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Internet of Things and Wearable Devices: A Mixed Literature Review

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Abstract

In recent years, the concept of the Internet of Things (IoT), its different models and emerging conceptual frameworks, have offered new opportunities for the integration of technologies into everyday life. Although initially based on the notion of the link between a physical device, its counterpart in a virtual environment and the technological aspects of that relationship, IoT-based wearable devices now offer multiple contributions to all types of users, from professionals and organizations to ordinary people. However, there are inaccuracies, abundant definitions, limited clarity in terms of trends, benefits, components, challenges and future lines of research. In this sense, a mixed literature review study was conducted. The mixed design, of dominant type (CUAN-qual), was composed of a quantitative analysis of bibliometric type and a qualitative analysis of thematic type and embedded in the first one. Data are provided on the main trends observed in the bibliometric indicators studied, a synthesis of some qualitative indicators of particular relevance and pertinence. In addition, future lines of research are presented to address strengths and challenges in this field.

Keywords: Internet of Things; wearable devices; bibliometrics.

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1. Introduction

Today, technological and social advances have made it possible to establish the *e-era* in most contexts, so that electronic devices connected to Internet servers are a common accessory, of daily use and, for some people, irreplaceable. The general notion that comprises the existence of a physical device, electronic in nature, that is connected to share data it collects through sensors and other components, is commonly referred to as Internet of Things (IoT). (1-3).
Related concepts have grown in popularity and exploitation capabilities recently, so that the link between physical devices, virtual environments and the interaction between the two represents an important platform for education. (4) (5) (6) (7) (8) (9) (10)(9); research (11); health care (12) (13) (14) (15) (16) (17) (18) Data mining and decision making (19) (20) (21) (22) (23) (24); the construction and study of social networks in virtual environments (25) (26) (27) (28) (29)

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(30)among others. Especially in the health area, where IoT has its own "universe", multiple fields such as rehabilitation, nursing, control of variables (pain, vital signs, quality of the environment), generation of databases for the study of clinical trials, among others, can be appreciated. (31) (32) (33) (34) (35) (36) (37) (38) (39) (40) .
It should be noted that as a concept with multiple technological and commercial applications, IoT is a growing field with several billion-dollar industries associated with it. (41). It is not only about the production of its components, but it ranges from applied nanotechnology to process control devices or environmental properties that, in both cases, materialize in devices that contribute significantly to the quality of life of human beings (1,42,43).
However, although apparently simple, this concept involves many complex aspects and there are numerous definitions in the literature, which has resulted, among other concomitant causes, in lower growth than expected in the previous decade. (1). Among these causes is that, although IoT technologies lower the costs of services and offer multiple functionalities, they are still expensive to produce, especially in terms of the development of biosensors and the technological infrastructure for their application (41,44,45). (41,44,45).
Other elements noted in the literature are challenges related to data security and privacy, social acceptance of the technology, strict latency, noise (data distortion) and the short battery life achieved by portable devices (46-49). Despite these difficulties, its main contribution is the realization of the concept of portable device or ubiquitous service (46,50-52)which forms the basis of imaginable and near futures such as *smart* cities (52). (52)*Smart* farming (53)*Smart houses* (1)and other technological environments regulated by the IoT concept and executed by portable, embedded, aggregated and interconnected devices (54-56). (54-56).
Precisely, although *doorbells* and smart cameras, air controllers and other similar devices have become popular and integrated into everyday life, *wearable* devices are *the* main trend in terms of technological integration through IoT (1,4,19-21). Particularly in the health sciences, multiple possibilities have been found for the exploitation of wearable devices, since they can measure vital signs in real time; extract data for the detection of infections and proteins; record complex variables such as medical adherence or warn of safety risks (57-60).
These services have also been used to measure the performance of athletes, recovering patients, professionals in adverse conditions and other populations. Even so, the literature points to the need for further research on the improvement of the services and their commercialization, the integration of the AI revolution, as well as their digitization and sustainability (61-64). Currently, *wearables* are produced in different formats such as bands, devices placed on wrists such as *smartwatches* or patches, headgear devices such as eyeglasses or hats, textiles and chest devices (41).
Because of its broad potential, both for the general population and for research and development of new technologies and integrated systems for decision making as a key source of data for the construction of knowledge. (65)an advanced bibliometric study is needed to identify the main trends in the study of wearable devices using IoT. To this end, the main trends in bibliometric indicators were analyzed, the patterns in these indicators were analyzed, and a general approach to this field of study was made to obtain a comprehensive overview, knowledge gaps, novel ideas and generate an approach to future contributions. (66-68).

2. Methods

In view of the purposes stated in the introduction, a mixed approach of systematic review of a dominant type was adopted, a decision taken in order to achieve a quantitative analysis as the main study, while the qualitative approach would be embedded and would allow a thematic analysis, similar to other studies with this approach. (66,69,70). This decision was made to complement the weaknesses of bibliometric designs and qualitative literature reviews, given that the former do not favor the triangulation of qualitative data and in the latter case bias is generated precisely due to drawing conclusions based on the authors' interpretations (66,71). (66,71) (72) (73) (74).
For the quantitative study, bibliometric analysis was selected as the methodology based on the following indicators: goals, criteria for use, scope, volume of the data set, and types of analysis. (66) (75) (76) (77) (78) . The selection was mediated by the fact that it aimed to synthesize large amounts of bibliometric data, with a broad review scope because the data set was too voluminous for manual reviews and the active character of the field expressed in rapidly growing literature (66,67).
The design of the research questions was based on the proposal of similar studies (67). (67) (79) (80) (81) (82) (83) (84)was aimed at clarifying the specific procedures of bibliometric analysis and their significance. Trends, areas, types of scientific production and collaboration, as well as the most frequent institutions and sources were explored (see Table 1).

Table 1. Questions and contributions to the study.

Questions	Contributions to the bibliometric study
What are the top publishing and citation trends in IoT AND Wearables?	Interpret past and future patterns in IoT AND Wearables.
What are the main areas of publication and citation of IoT AND Wearables studies?	Identify key areas and for future studies
What are the most common types of scientific manuscripts and what kinds of collaborations produce them?	Identify the most appropriate designs for scientific production and communication, as well as the best ways to organize research teams in IoT AND Wearables.
Which are the institutions and journals most	Contribute to the identification of future

interested in scientific production in the IoT AND Wearables area?	sources of collaboration for scientific projects, selection of areas or problems related to the lines of research.

The search strategy was based on an advanced search in the Scopus database, with a defined time frame (2013-2022), without restrictions in terms of auxiliary indicators (language, geographic region, type of text, domain). For this purpose, the search command TITLE-ABS-KEY ("Internet of Things" OR "IoT") AND TITLE-ABS-KEY (wearables) was used.

The bibliometric analysis was produced in three dimensions: performance analysis, science mapping, and network analysis (66). This design made it possible to analyze the impact of citations weighted by field; the total number of authors, documents and citations; the number of citations per document; authors, institutions and sources; as well as topic, cluster and co-occurrence analyses of terms (85) (86) (87). For network analysis and data representation, the VOSviewer software and the SciVal tool were used, similar to preceding studies (88).

The thematic analysis was carried out in an embedded manner in the main study and its main objective was to explore the main trends within a small selection of texts, similar to previous studies (89). (89) (90). To this end, 10 articles were selected according to two fundamental criteria: relevance and pertinence.

The body of texts was studied through four *a priori* selected topics of interest: benefits and contributions of technology, types of devices and formats, technological-conceptual components and challenges. For this purpose, the authors selected from sets the texts in the sample (*n=10*), coded fragments of texts (coding) and synthesized these fragments according to the common elements and themes initially selected (categorization), until no notable new information was found.

3. Results and Discussion

Bibliometric analysis

The first analysis performed was that of total publications, authors and citations. These metrics were explored in terms of temporal trends, with an increasing trend until the early 2020s, where a shift towards stabilization of total scientific production is seen (see Figure 1).

In global terms, a total of 1341 documents were retrieved, produced by a total of 4568 authors, resulting in approximately three authors per document.

In terms of total citations, this metric, together with the analysis of temporal trends, provides a clear indication of the vitality of the field (IoT + Wearables), reaching 24670 (18.4 citations per document). However, the main evidence of the impact of the research analyzed and its visibility is found in the *Field-Weighted Citation Impact*, with a value of 2.13, which implies that these have been cited, on average, more than twice the expected citations.

These results are in contrast with data consulted in the literature, which states that growth was lower than expected in the previous decade. (1). However, it is necessary to understand the *delay* between scientific production, R&D results in the industry, and the effective commercialization of these advances, which is evidenced by the growing attractiveness and potential applications of IoT systems (49).

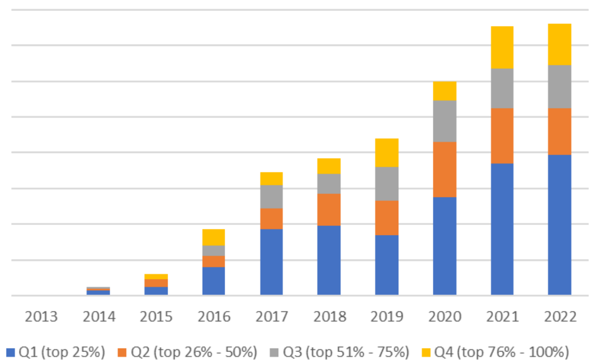

Figure 1. Scientific production by quartiles.

Regarding the type of scientific communication, the data show a considerable majority of *conference papers*, followed by original research articles (see Table 2). Other studies consulted do not emphasize this type of metric, which could shed light on the current stage of the field. These results point to a period of consolidation, with a predominance of transfer over original production, which highlights the boom of the field, a fact contrasted in the volume of texts placed in Q1 according to ScimagoJR.

Table 2. Types of publications.

Publication types	Ndoc
Conference Paper	657
Article	435
Chapter	119
Review	81
Conference Review	22
Editorial	11
Book	10
Note	2
Others	4

The geographical analysis also shows that this vitality has not been regional in nature, but that there is a significant dispersion, although in terms of countries, Europe, the Middle East and India stand out regionally (see Figure 2). Latin America and Africa are the regions least interested in these technological systems, which could be explained by the costs associated with the production of biosensors and other technological components required for IoT + Wearables integration. In terms of countries, the USA stands out with a total of 308 publications, which, together with Canada, makes North America a leading region in the study of the field.

Figure 2. Geographical distribution

Regarding authorial collaboration, a significant fact is the low frequency of texts produced by a single author, with only 8.5% (see Figure 2). This highlights the complexity of the research designs and processes, which, coupled with the distribution of research areas and disciplines involved in the study of IoT + Wearables. Another noteworthy fact is that, despite the predominance of institutional collaboration in total number of documents, the FWCI (3.16) shows that the citation of international collaboration in this field is much higher than expected, while national and institutional collaborations exceed the anticipated citations by 88% and 91%, respectively (see Table 3).

Table 3. Distribution of author collaboration by subtypes.

Type of collaboration	Ndoc	%Ndoc	Cpd	FWCI
International collaboration	356	26.5%	29,4	3,16
Only national collaboration	333	24.8%	14,4	1,88
Only institutional collaboration	514	38.3%	15,2	1,91
No collaboration	114	8.5%	14,2	1,1

As for the most outstanding institutions, the predominance of academic centers stands out, with 119 of the total of 151 documents produced by the *top 10*, for 79.33% (see Table 4). In this section, the FWCI of the articles produced by IBM (N=18) stands out with a value of 3.59, in addition to a total number of citations of 533.

Table 4. Top 10 institutions.

Institution	Sector	Country	Ndoc	FWCI	Ncit
Anna University	academic	India	30	1,67	112
Tampere University	academic	Finland	20	2,64	426
IBM	corporate	United States	18	3,59	533
Intel	corporate	United States	13	1,71	203
Amity University, Noida	academic	India	12	1,49	34
Karlsruhe Institute of Technology	academic	Germany	12	1,77	190
Swiss Federal Institute of Technology Zurich	academic	Switzerland	12	3,21	386
University of Illinois at Urbana-Champaign	academic	United States	12	1,46	152
Vellore Institute of Technology	academic	India	12	4,92	108
Georgia Institute of Technology	academic	United States	9	2,93	198

In terms of the main sources, the top 20 in Scopus demonstrate the interdisciplinary vitality of the field. The first in terms of total number of documents and citations, Sensors (Q1 Analytical Chemistry by SJR 2022), includes a total of six areas and seven categories, ranging from chemical, medical, physical, information systems, electrical and electronic engineering disciplines. As for those with the highest FWCI, Electronics (Q2 Computer Networks and Communications by SJR 2022) covers two areas (computer science and engineering) and five categories, while IEEE Access (Q1 Computer Sciences SJR 2022) and Intelligent Systems Reference Library (Q4 Computer Sciences SJR 2022) cover three areas and an equal number of categories, spanning computer science, information systems management, materials science and engineering. It is worth noting that, of the 20 sources, only 5 received a citation below the world average (see Table 5).

Table 5. Top 20 Scopus sources.

Scopus Source	Ndoc	FWCI	Ncit
Sensors	49	1,94	1222
IEEE Internet of Things Journal	29	2,75	1048
IEEE Access	28	6,59	3267
Lecture Notes in Computer Science	27	0,87	128
ACM International Conference Proceeding Series	26	0,7	137
Advances in Intelligent Systems and Computing	15	1,73	85
Communications in Computer and Information Science	11	0,7	21
Lecture Notes in Electrical Engineering	10	2,93	29
Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering	10	0,62	34
Proceedings of the Annual Hawaii International Conference on System Sciences	10	1,9	27
EAI/Springer Innovations in Communication and Computing	9	2,18	37
Lecture Notes in Networks and Systems	9	1,31	12
Computer	8	1,59	187
Electronics (Switzerland)	8	3,26	559
CEUR Workshop Proceedings	7	0,16	3
International Congress on Ultra Modern Telecommunications and Control Systems and Workshops	7	1,8	40
IEEE Sensors Journal	6	1,42	83
Intelligent Systems Reference Library	6	5,98	95
Proceedings - Electronic Components and Technology Conference	6	3,9	83
Wireless Communications and Mobile Computing	6	1,71	57

These data highlight the multidisciplinary nature and interdisciplinary trends of the field, with a special link between the areas of computer sciences and engineering (see Figure 3). However, it is necessary to deepen these relationships, as the applied *clustering* procedure revealed a higher agglomeration in the areas of mathematics, computer sciences and physics, with a lower development in medical and health sciences, as well as in chemical sciences (see Figure 3). A possible hypothesis to explain this distribution has to do with the important basis provided by mathematical models for the development of IoT systems and their refinement through learning techniques, which could diminish the impact of research lines directly related to *Wearables*.

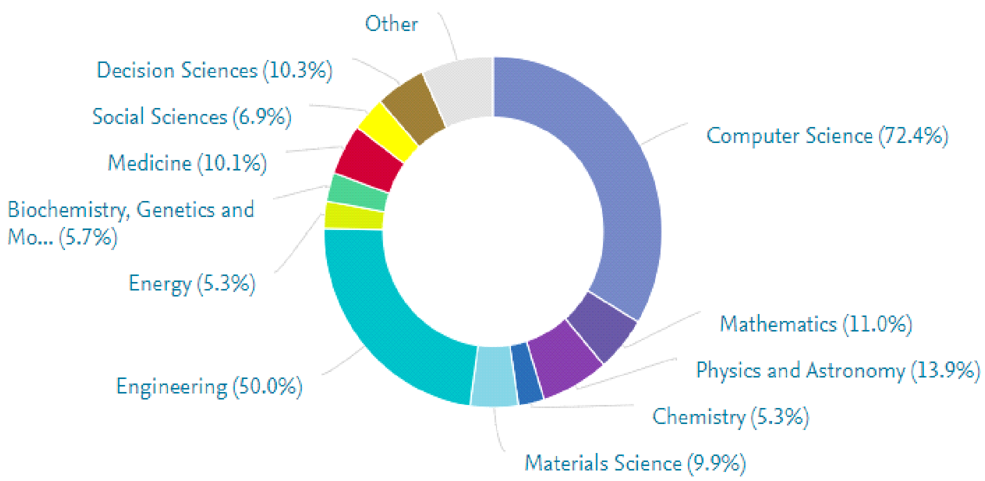

Figure 4. Subject areas.

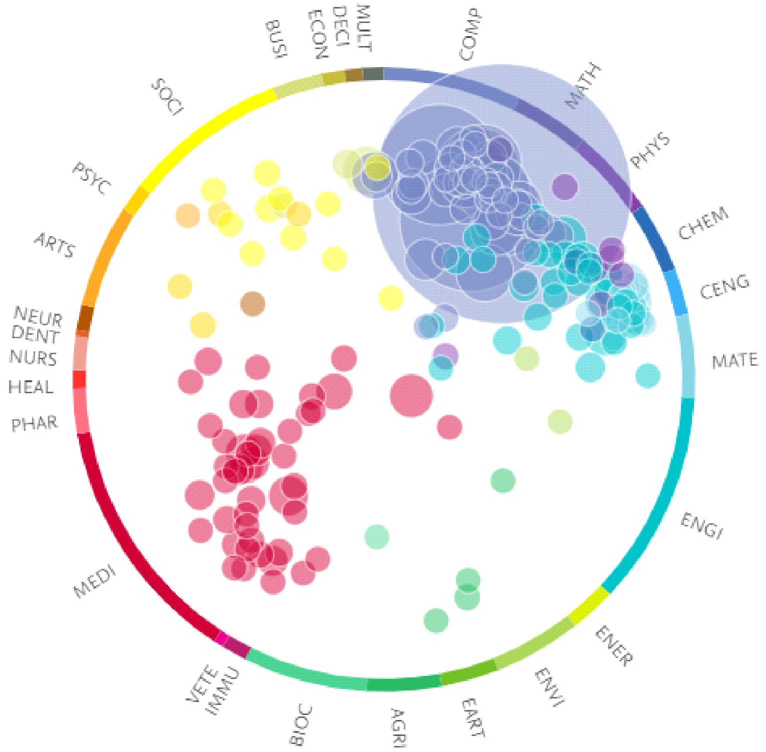

Figure 5. Themes and thematic clusters.

The visualization of the co-occurrence of terms supports these previous analyses, with IoT remaining as the main and most prevalent line (see Figure 6), from which Wearable technologies and the multiple applications of both and their relationships with other technologies are derived. It also highlights several of the benefits identified in the literature, components, models and learning systems, as well as challenges. This co-occurrence of terms was used for the embedded qualitative analysis and the design of the four fundamental themes elaborated *a priori*.

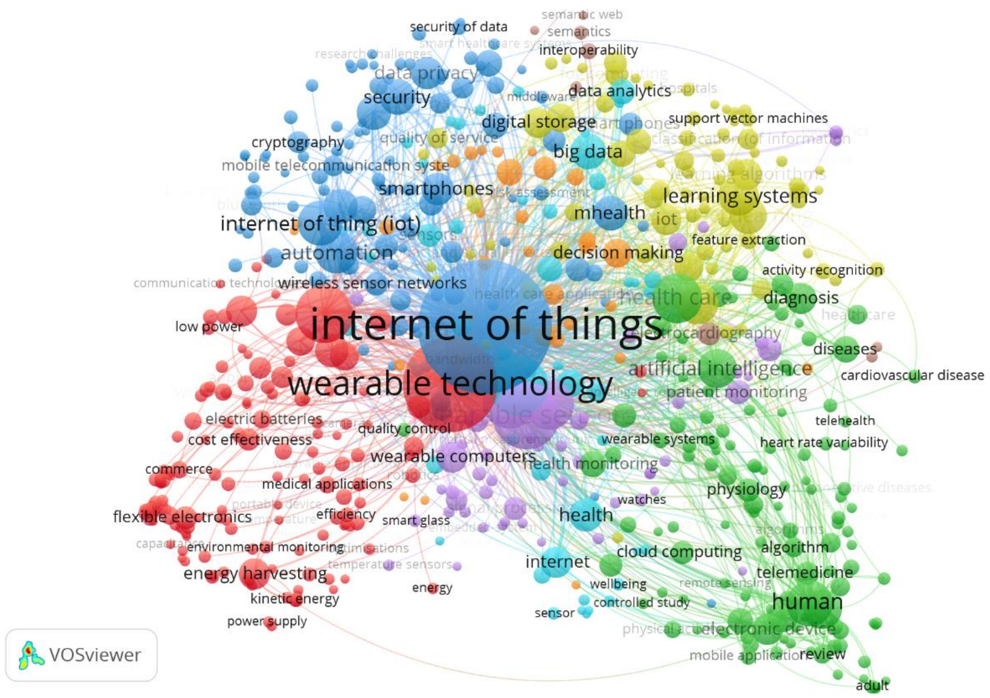

Figure 6. Co-occurrence of terms.

Embedded qualitative analysis and summary of thematic analysis

The qualitative analysis showed an internal tendency (not generalizable) to experimental designs, which was noted in the articles and in the results of the reviews consulted. In addition, it highlighted important benefits such as their ubiquity, the reduction of costs in services, the broad possibilities offered by real-time monitoring and data processing, as well as a trend towards the expansion of capabilities and applications, especially in the fields of health and *e-environment.*

Another noteworthy aspect is the diversity of formats that are studied and implemented in wearable technology, as well as its multi- and interdisciplinary connection with other fields for the improvement of IoT systems and the services in which they are used. Similarly, the data analyzed point to a steady movement towards wearable technology in everyday life and important benefits beyond diagnostics and measurement.

However, they highlight the emphasis on limitations, both technological and those included or resulting from their transfer to everyday life. Particularly noteworthy are the issues related to data use, privacy, decision making based on the data contained in the *cloud* and issues that highlight the social aspects of technological integration and digital transformation. These results are in line with those found in similar studies (91) (92) (93).

Table 6. Summary of qualitative analysis.

Study and relevance	Design	Summary of the thematic analysis
(41) Biosensors and Bioelectronics 20.6 CiteScore 12.6 Impact Factor Scimago Q1 Biophysics Google citations: 67 Scopus Citations: 45	Review design. Thematic analysis without defined protocol	IoT-enabled wearable devices contribute to lowering healthcare costs and offloading responsibilities from weak healthcare systems. They support decision making, offer reliable metrics and have a variety of applications (data analysis, diagnostics, imaging, telemedicine). The main types of portable devices are wrist, chest, head, graftable or tattooable, textile. The components are divided into those of the IoT system and those of the portable system. The former are the system's own server, the signal amplifier, the *front end module* and the antenna; while the latter are the connectivity chips, processors, *actuators*, sensors, App processor, communications module and connection manager. The main limitations and challenges are high network latency; poor design; short battery life; limited computational capacity; expanding coverage areas; strengthening security, privacy and data availability.
(1) Technological Forecasting and Social Change 17.2 CiteScore 12 Impact Factor Scimago Q1 Applied Psychology Google citations: 25 Scopus Citations: 6	*Comprehensive systematic literature review*. Background review design. Thematic analysis to formulate a common definition.	Applications in business management, extending services from specialized sectors to the general population and everyday life, Types and formats similar to those described in (41). Conceptual components: ubiquity and uniqueness; standardized technologies; interaction between the physical device and its virtual counterpart; data, information and sensors; user and service. Need to integrate other conceptual components outside the strictly technological ones. Challenges related to security, privacy and availability, similar to (3), but with emphasis on the IoT system, not the *wearable*.
(42) Nano Energy 29.3 CiteScore 17.6 Impact Factor Scimago Q1 Electrical and Electronic Engineering Google citations: 112 Scopus Citations: 96	*Comprehensive systematic literature review*. Background review design. Thematic analysis with emphasis on sensors and portable chemical systems.	Advances in integrated systems in tattoos and patches; advances in the integration of sensors for tear and saliva detection; advances in microneedle technology for dispensing treatments through sensitive therapeutic systems. Emphasis on integrated systems (micro sensors, communication modules, battery, dispenser). Complexity of miniaturization processes, manufacturing, *wireless* data transmission and bio-compatibility analysis.
(94) Computer Communications 11 CiteScore 6 Impact Factor	Experimental study.	Support for rehabilitation, recovery and return to the courts; appropriate use of metrics using *machine learning* techniques, *deep learning* and continuous predictive mathematical models. Emphasis on data processing, noise elimination and weak applications in mHealth systems.

Scimago Q1 Computer Networks and Communications Google citations: 102 Scopus Citations: 69		
(95) Measurement 9 CiteScore 5.6 Impact Factor Scimago Q1 Applied Mathematics Google citations: 61 Scopus Citations: 52	Experimental study.	Miniaturization, portable design, intelligent monitoring and advanced metrics of cardiac performance during sports activity. Components: ZigBee wireless sensor, Bluetooth, PC or Smartphone and a cloud (*cloud platform*).
(57) Biosensors and Bioelectronics 20.6 CiteScore 12.6 Impact Factor Scimago Q1 Biomedical Engineering Google citations: 93 Scopus Citations: 84	Experimental study	Simple design, expands use to everyday life, low cost, non-invasive nature and breadth of utilities (e.g., disposable). Portable device in patch format, detecting sensors, microfluidic channels based on cotton threads, imaging module with UV-LED lamps (*3D printer designed*), Smartphone App and integrated IoT system. Progress is needed in the study of individual biological differences and the development of a processing system for the use of real-time data.
(58) Sensors and Actuators B: Chemical 14.6 CiteScore 8.4 Impact Factor Scimago Q1 Condensed Matter Physics Google citations: 16 Scopus Citations: 13	Experimental study	It overcomes one of the main problems of this type of wearable, the transmission of data in real time. Device consisting of a solid-state ion selective electrode, a miniaturized printed circuit board (PCB) for metric reading and processing. The IoT system is based on a *low-power* Wi-Fi interface, transmitting real-time data to a smartphone app.
(59) Computers in Biology and Medicine 9.2 CiteScore 7.7 Impact Factor Scimago Q1 Computer Science Applications Google citations: 70 Scopus Citations: 58	Experimental study	Diagnostic system based on a deep learning model based on neural networks. Ubiquitous access and targeted convolutional neural network architecture for lung cancer imaging that reduces cost and physical checks. The IoT system draws on data from computer-aided tomography (CAT) scans and sensor data. It does not automate the diagnosis, but it is an auxiliary tool.
(55) Pervasive and Mobile Computing 8 CiteScore 4.3 Impact Factor Scimago Q1 Applied Mathematics Google citations: 9 Scopus Citations: 7	Experimental study	Offers a non-invasive alternative for monitoring the breathing of pre-term infants. Promotes parental psychological coping by reducing the need for the *display* of medical devices. Smart-textile type wearable for chest, consisting of a biosensor belt, measurement device and communication module based on an IoT system with network architecture. Low latency in data processing and communication.
(61) Computer Methods and Programs in Biomedicine 10.1 CiteScore 6.1 Impact Factor	Review article	Relationship between IoT, wearables and AI to improve data processing through different learning models. Variety of applications ranging from monitoring in health, sports, diagnostic assistance, pattern detection, etc. The main limitations are related to the use, privacy, protection, transmission and permissions for data processing.

Scimago Q1 Computer Science Applications Software Google citations: 91 Scopus Citations: 65		

Limitations of the study and future approaches

The study had limitations intrinsic to its design, which were expressed in the excessive generality of the results, although this was a strength for the identification of trends, areas, types of scientific production and collaboration, as well as the most frequent institutions and sources. Another limitation lies in the selection of a single database (Scopus), as pointed out by previous studies (67,68). (67,68).

The data consulted and the embedded qualitative analysis pointed to the importance of future studies with mixed design, both review and research, that favor greater depth in the examination of trends, results, applications, specific areas (multi- and interdisciplinary integration) and challenges of IoT-enabled wearable devices.

4. Conclusions

In the present study, both in the bibliometric and thematic analysis, the growing interest in wearable devices based on IoT models was evident, expressed both in the increase in the total number of publications in world-class journals and in their impact, measured in total citations and in their normalized metrics (FWCI). Furthermore, this growth trend is expressed in the multi- and interdisciplinary linkages identified in the clusters and the co-occurrence of terms.

The findings reviewed point to a period of knowledge transfer and original production, especially through experimental design and review studies. These data support the scientific relevance of the field, which is further supported by multiple benefits, especially in the areas of health and sports, as well as future applications in *e-environment* and new portable device formats capable of dispensing treatments and controlling complex variables.

In a general sense, in addition to future studies to improve connectivity and the ubiquitous nature of the service, further studies are needed on security, access, protection and privacy, as well as high quality data processing. Other lines to be developed should be related to the development of business models, technological integration in the daily life of non-specialized users, social acceptance of the technology, exploration of future and novel applications of portable devices, as well as the reduction of stated limitations and challenges.

References

[1] Sorri K, Mustafee N, Seppänen M. Revisiting IoT definitions: A framework towards comprehensive use. Technological Forecasting and Social Change 2022;179:121623. https://doi.org/10.1016/j.techfore.2022.121623.

[2] Perez AJ, Siddiqui F, Zeadally S, Lane D. A review of IoT systems to enable independence for the elderly and disabled individuals. Internet of Things 2023;21:100653. https://doi.org/10.1016/j.iot.2022.100653.

[3] Gonzales Tito YM, Quintanilla López LN, Pérez Gamboa AJ. Metaverse and education: a complex space for the next educational revolution. Metaverse Basic and Applied Research 2023;2:56. https://doi.org/10.56294/mr202356.

[4] Gonzalez-Argote J, Lepez CO, Castillo-Gonzalez W, Bonardi MC, Cano CAG, Vitón-Castillo AA. Use of real-time graphics in health education: A systematic review. EAI Endorsed Transactions on Pervasive Health and Technology 2023;9.

[5] Álvarez Loyola C. The NOOCs as a training strategy for teachers in the use of technological tools in primary education. Reg Cient 2023:202362. https://doi.org/10.58763/rc202362.

[6] Gonzalez-Argote D. Immersive environments, Metaverse and the key challenges in programming. Metaverse Bas App Res 2022;1:6. https://doi.org/10.56294/mr20226.

[7] Lepez CO, Simeoni IA. Pedagogical experience with Public Health campaigns from the design of socio-educational projects with insertion in the local territory. Community and Interculturality in Dialogue 2023;3:74. https://doi.org/10.56294/cid202374.

[8] Veloz Montano MDLN, Keeling Álvarez M. The educational and pedagogical intervention in scientific research. Community and Interculturality in Dialogue 2023;3:70. https://doi.org/10.56294/cid202370.

[9] Laplagne Sarmiento C, Urnicia JJ. B-learning protocols for information literacy in Higher Education. Reg Cient 2023:202373. https://doi.org/10.58763/rc202373.

[10] Romero Torres ME, Gamero De La Espriella P. Creation of a techno-pedagogical model for the strengthening of the Emberá Katío language through ancestral customs at the El Rosario educational institution in Tierralta. Reg Cient 2023:202398. https://doi.org/10.58763/rc202398.

[11] Vitón-Castillo AA, Fajardo Quesada AJ, Romero Valdes YDLC, Batista Rivero L. Metaverse: an emerging research area. Metaverse Bas App Res 2022:3. https://doi.org/10.56294/mr20223.

[12] Díaz-Chieng LY, Auza-Santiváñez JC, Robaina Castillo JI. El futuro de la salud en el metaverso. Metaverse Bas App Res 2022;1:1. https://doi.org/10.56294/mr20221.

[13] Gonzalez-Argote J. Uso de la realidad virtual en la rehabilitación. Interdisciplinary Rehabilitation / Rehabilitacion Interdisciplinaria 2022;2:24. https://doi.org/10.56294/ri202224.

[14] Canova Barrios CJ, Macarena Francisco S, Hereñú MP. Workplace Violence in the Health Sector: Focus on the Argentinean context. Community and Interculturality in Dialogue 2022;2:31. https://doi.org/10.56294/cid202231.

[15] Mejías M, Guarate Coronado YC, Jiménez Peralta AL. Inteligencia artificial en el campo de la enfermería. Implicaciones en la asistencia, administración y educación. Sal Cienc Tec 2022;2:88. https://doi.org/10.56294/saludcyt202288.

[16] Gómez Cano CA, Sánchez Castillo V. Estructura del conocimiento en rehabilitación dentro y fuera del área de la Medicina: Perspectivas Bibliométricas de las categorías «Physical Therapy, Sports Therapy and Rehabilitation» y «Rehabilitation». Interdisciplinary Rehabilitation / Rehabilitacion Interdisciplinaria 2022;2:22. https://doi.org/10.56294/ri202222.

[17] Campos Sánchez CM, Guillén León LA, Acosta Yanes RC, Gil Oloriz MA. Metaverso: el futuro de la medicina en un mundo virtual. Metaverse Bas App Res 2022;1:4. https://doi.org/10.56294/mr20224.

[18] Gil Oloriz MA, Roche Beltrán C, Campos Sánchez CM. Trends in health telematics and telemedicine services. Data Metadata 2022;1:16. https://doi.org/10.56294/dm202216.

[19] Becerra MDC, Aballay A, Romagnano M. Reflections on Healthcare Document Management in the Age of 4.0 Technologies. Data Metadata 2023;2:52. https://doi.org/10.56294/dm202352.

[20] Torres ER, Cano CAG, Castillo VS. Management information systems and their impact on business decision making. Data and Metadata 2022;1:21-21.

[21] Robaina Castillo JI. Identifying promising research areas in health using bibliometric analysis. Data & Metadata 2022:10. https://doi.org/10.56294/dm202210.

[22] Ledesma F, Malave González BE. Bibliometric indicators and decision making. Data & Metadata 2022:9. https://doi.org/10.56294/dm20229.

[23] Diaz-de La Rosa C, Jiménez-Franco LE, Toledo Del Llano R, Vega-Cardulis E, Cardulis-Cárdenas O. Trends, collaboration and impact of Latin American scientific production in anesthesiology and pain medicine in Scopus and Web of Science. Data Metadata 2022;1:13. https://doi.org/10.56294/dm202213.

[24] Eslava Zapata R, Chacón Guerrero E, Gómez Ortiz E, Mogrovejo Andrade J. Decision-making in organizations: process and strategies. Data and Metadata 2022;1:19. https://doi.org/10.56294/dm202219.

[25] Gómez Cano CA, Sánchez Castillo V, Clavijo Gallego TA. Mapping the Landscape of Netnographic Research: A Bibliometric Study of Social Interactions and Digital Culture. Data & Metadata 2023:25. https://doi.org/10.56294/dm202325.

[26] Vera JJ, Barroso N. Addressing problematic consumption: an action research experience from the Social Network Analysis. AWARI 2020;1:e022. https://doi.org/10.47909/awari.83.

[27] Duarte Mascarenhas HA, Rodrigues Dias TM, Mascarenhas Dias P. Adoption of Network Analysis Techniques to Understand the Training Process in Brazil. AWARI 2020;1:e004. https://doi.org/10.47909/awari.63.

[28] Benito PV. Contemporary art and networks: Analysis of the Venus Project using the UCINET software. AWARI 2022;3. https://doi.org/10.47909/awari.166.

[29] Gutiérrez EM, Larrosa JMC. Popularity in Facebook Pages: What role network structural variables play? AWARI 2020;1:e005. https://doi.org/10.47909/awari.68.

[30] Dos Santos JH, De Macedo DDJ. Behavioral analysis of indicators related to the user profiles of the Mettzer platform. En: Rodrigues Dias TM, editor. Advanced Notes in Information Science, vol. 2, ColNes Publishing; 2022. https://doi.org/10.47909/anis.978-9916-9760-3-6.102.

[31] Toconas LDC. Empathy in nursing professionals for care subjects with depression. Community and Interculturality in Dialogue 2023;3:67. https://doi.org/10.56294/cid202367.

[32] Mallqui Cáceres YM. Management of pain reduction in mechanically ventilated care subjects. Interdisciplinary Rehabilitation / Rehabilitacion Interdisciplinaria 2023;3:59. https://doi.org/10.56294/ri202359.

[33] Mendoza Rivas L, Martínez Cruz L. Revisión de ensayos clínicos sobre la eficacia de la rehabilitación cognitiva en pacientes con lesión cerebral traumática. Interdisciplinary Rehabilitation / Rehabilitacion Interdisciplinaria 2022;2:25. https://doi.org/10.56294/ri202225.

[34] Ron M, Pérez A, Hernández-Runque E. Nivel de riesgo para la salud y predicción del dolor musculo-esqueletico en trabajadores en condiciones de teletrabajo: Un enfoque matricial. Interdisciplinary Rehabilitation / Rehabilitacion Interdisciplinaria 2023;3:40. https://doi.org/10.56294/ri202340.

[35] Veloz Montano MDLN, González Martínez MDLC, Pérez Lemus L. Rehabilitation of occupational stress from the perspective of Health Education. Community and Interculturality in Dialogue 2023;3:71. https://doi.org/10.56294/cid202371.

[36] Jaramillo Sancho K, Valenzuela Sánchez GP. Biomarcadores utilizados para el diagnóstico y pronóstico en lupus eritematoso sistémico. Salud, Ciencia y Tecnología 2023;3:422. https://doi.org/10.56294/saludcyt2023422.

[37] Silva Infantes M, Sánchez Soto JM, Astete Montalvo MA, Ruiz Nizama JL, Velarde Dávila L, Dávila-Morán RC, et al. Analysis of the perception of health professionals regarding the incorporation of emerging technologies in their practice. Salud, Ciencia y Tecnología 2023;3:565. https://doi.org/10.56294/saludcyt2023565.

[38] Cervantes Martínez L, Farías Rojas GA, Villota Oyarvide W, Del Campo Saltos G. Knowledge generation in the telecommunications era and its impact on education and economic development in Latin American. Salud Cienc Tecnol 2023:363. https://doi.org/10.56294/saludcyt2023363.

[39] Madkar S, Pardeshi S, Kumbhar MS. Machine learning based efficient routing protocol in wireless sensor network. Salud Cienc Tecnol 2022;2:195. https://doi.org/10.56294/saludcyt2022195.

[40] Alonso Galbán P, Izquierdo Pamias T. Integración de herramientas web 2.0 en los sitios de especialidades y temas de salud para el desarrollo de comunidades virtuales de práctica en la red Infomed. Salud Cienc Tecnol 2022;2:121. https://doi.org/10.56294/saludcyt2022121.

[41] Verma D, Singh KR, Yadav AK, Nayak V, Singh J, Solanki PR, et al. Internet of things (IoT) in nano-integrated wearable biosensor devices for healthcare applications. Biosensors and Bioelectronics: X 2022;11:100153. https://doi.org/10.1016/j.biosx.2022.100153.

[42] Wen F, He T, Liu H, Chen H-Y, Zhang T, Lee C. Advances in chemical sensing technology for enabling the next-generation self-sustainable integrated wearable system in the IoT era. Nano Energy 2020;78:105155. https://doi.org/10.1016/j.nanoen.2020.105155.

[43] Singh KR, Nayak V, Singh J, Singh RP. Nano-enabled wearable sensors for the Internet of Things (IoT). Materials Letters 2021;304:130614. https://doi.org/10.1016/j.matlet.2021.130614.

[44] Dao N-N. Internet of wearable things: Advancements and benefits from 6G technologies. Future Generation Computer Systems 2023;138:172-84. https://doi.org/10.1016/j.future.2022.07.006.

[45] Verma H, Chauhan N, Awasthi LK. A Comprehensive review of 'Internet of Healthcare Things': Networking aspects, technologies, services, applications, challenges, and security concerns. Computer Science Review

2023;50:100591. https://doi.org/10.1016/j.cosrev.2023.100591.
[46] Lakhan A, Abdul Lateef AA, Abd Ghani MK, Abdulkareem KH, Mohammed MA, Nedoma J, et al. Secure-fault-tolerant efficient industrial internet of healthcare things framework based on digital twin federated fog-cloud networks. Journal of King Saud University - Computer and Information Sciences 2023;35:101747. https://doi.org/10.1016/j.jksuci.2023.101747.
[47] Bojjagani S, Seelam NR, Sharma NK, Uyyala R, Chandra Murthy Akuri SR, Maurya AK. The Use of IoT-based Wearable Devices to Ensure Secure Lightweight Payments in FinTech Applications. Journal of King Saud University - Computer and Information Sciences 2023:101785. https://doi.org/10.1016/j.jksuci.2023.101785.
[48] Lederman R, Ben-Assuli O, Vo TH. The role of the Internet of Things in Healthcare in supporting clinicians and patients: A narrative review. Health Policy and Technology 2021;10:100552. https://doi.org/10.1016/j.hlpt.2021.100552.
[49] Maddikunta PKR, Pham Q-V, Nguyen DC, Huynh-The T, Aouedi O, Yenduri G, et al. Incentive techniques for the Internet of Things: A survey. Journal of Network and Computer Applications 2022;206:103464. https://doi.org/10.1016/j.jnca.2022.103464.
[50] Rahman MdS, Peeri NC, Shrestha N, Zaki R, Haque U, Hamid SHA. Defending against the Novel Coronavirus (COVID-19) outbreak: How can the Internet of Things (IoT) help to save the world? Health Policy and Technology 2020;9:136-8. https://doi.org/10.1016/j.hlpt.2020.04.005.
[51] Abuwarda Z, Mostafa K, Oetomo A, Hegazy T, Morita P. Wearable devices: Cross benefits from healthcare to construction. Automation in Construction 2022;142:104501. https://doi.org/10.1016/j.autcon.2022.104501.
[52] Rahman MA, Hossain MS, Showail AJ, Alrajeh NA, Alhamid MF. A secure, private, and explainable IoHT framework to support sustainable health monitoring in a smart city. Sustainable Cities and Society 2021;72:103083. https://doi.org/10.1016/j.scs.2021.103083.
[53] Zhang M, Wang X, Feng H, Huang Q, Xiao X, Zhang X. Wearable Internet of Things enabled precision livestock farming in smart farms: A review of technical solutions for precise perception, biocompatibility, and sustainability monitoring. Journal of Cleaner Production 2021;312:127712. https://doi.org/10.1016/j.jclepro.2021.127712.
[54] Mavrogiorgou A, Kiourtis A, Kyriazis D. A pluggable IoT middleware for integrating data of wearable medical devices. Smart Health 2022;26:100326. https://doi.org/10.1016/j.smhl.2022.100326.
[55] Cay G, Solanki D, Rumon MAA, Ravichandran V, Hoffman L, Laptook A, et al. NeoWear: An IoT-connected e-textile wearable for neonatal medical monitoring. Pervasive and Mobile Computing 2022;86:101679. https://doi.org/10.1016/j.pmcj.2022.101679.
[56] Al Bassam N, Hussain SA, Al Qaraghuli A, Khan J, Sumesh EP, Lavanya V. IoT based wearable device to monitor the signs of quarantined remote patients of COVID-19. Informatics in Medicine Unlocked 2021;24:100588. https://doi.org/10.1016/j.imu.2021.100588.
[57] Ardalan S, Hosseinifard M, Vosough M, Golmohammadi H. Towards smart personalized perspiration analysis: An IoT-integrated cellulose-based microfluidic wearable patch for smartphone fluorimetric multi-sensing of sweat biomarkers. Biosensors and Bioelectronics 2020;168:112450. https://doi.org/10.1016/j.bios.2020.112450.
[58] Ozer T, Agir I, Henry CS. Low-cost Internet of Things (IoT)-enabled a wireless wearable device for detecting potassium ions at the point of care. Sensors and Actuators B: Chemical 2022;365:131961. https://doi.org/10.1016/j.snb.2022.131961.
[59] Faruqui N, Yousuf MA, Whaiduzzaman M, Azad AKM, Barros A, Moni MA. LungNet: A hybrid deep-CNN model for lung cancer diagnosis using CT and wearable sensor-based medical IoT data. Computers in Biology and Medicine 2021;139:104961. https://doi.org/10.1016/j.compbiomed.2021.104961.
[60] Zhu M, Yi Z, Yang B, Lee C. Making use of nanoenergy from human – Nanogenerator and self-powered sensor enabled sustainable wireless IoT sensory systems. Nano Today 2021;36:101016. https://doi.org/10.1016/j.nantod.2020.101016.
[61] Nahavandi D, Alizadehsani R, Khosravi A, Acharya UR. Application of artificial intelligence in wearable devices: Opportunities and challenges. Computer Methods and Programs in Biomedicine 2022;213:106541. https://doi.org/10.1016/j.cmpb.2021.106541.
[62] Fouad H, Mahmoud NM, Issawi MSE, Al-Feel H. Distributed and scalable computing framework for improving request processing of wearable IoT assisted medical sensors on pervasive computing system. Computer Communications 2020;151:257-65. https://doi.org/10.1016/j.comcom.2020.01.020.
[63] Chang V, Doan LMT, Ariel Xu Q, Hall K, Anna Wang Y, Mustafa Kamal M. Digitalization in omnichannel healthcare supply chain businesses: The role of smart wearable devices. Journal of Business Research 2023;156:113369. https://doi.org/10.1016/j.jbusres.2022.113369.
[64] Kim E, Han S. Investigating the digital health acceptance of Korean baby boomers: Comparative study of telemedicine and wearable healthcare devices. Health Policy and Technology 2023;12:100727. https://doi.org/10.1016/j.hlpt.2023.100727.
[65] Pérez Gamboa AJ, Gómez Cano CA, Sánchez Castillo V. Decision making in university contexts based on knowledge management systems. Data and Metadata 2023;1:92. https://doi.org/10.56294/dm202292.
[66] Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research 2021;133:285-96. https://doi.org/10.1016/j.jbusres.2021.04.070.
[67] Kamran M, Khan HU, Nisar W, Farooq M, Rehman S-U. Blockchain and Internet of Things: A bibliometric study. Computers & Electrical Engineering 2020;81:106525. https://doi.org/10.1016/j.compeleceng.2019.106525.
[68] Tandon A, Kaur P, Mäntymäki M, Dhir A. Blockchain applications in management: A bibliometric analysis and literature review. Technological Forecasting and Social Change 2021;166:120649. https://doi.org/10.1016/j.techfore.2021.120649.
[69] Akbarighatar P, Pappas I, Vassilakopoulou P. A sociotechnical perspective for responsible AI maturity models: Findings from a mixed-method literature review. International Journal of Information Management Data Insights 2023;3:100193. https://doi.org/10.1016/j.jjimei.2023.100193.
[70] Kim C, Capellan JA, Adler A. Exploring the empirical literature on mass shooting: A mixed-method systematic review of peer-reviewed journal articles. Aggression and

Violent Behavior 2021;58:101584. https://doi.org/10.1016/j.avb.2021.101584.

[71] Linnenluecke MK, Marrone M, Singh AK. Conducting systematic literature reviews and bibliometric analyses. Australian Journal of Management 2020;45:175-94. https://doi.org/10.1177/0312896219877678.

[72] Mariano AG, Prats GM. Capacidades tecnológicas en empresas sociales emergentes: una ruta de impacto social. Región Científica 2023;2:2023111-2023111.

[73] Castillo VS, Cano CAG, Gonzalez-Argote J. An Analysis of Research Trends and Knowledge Structure in the Field of Affordable and Clean Energy. EAI Endorsed Transactions on Energy Web 2022;9:e4-e4.

[74] Gómez Cano CA, Sánchez Castillo V, Ballen Losada Y, Bermudez Monje MA. Análisis de los riesgos asociados a la prestación de servicios en sala de enfermedades respiratorias durante la pandemia COVID-19 en el Hospital María Inmaculada. Salud Cienc Tecnol 2022:123. https://doi.org/10.56294/saludcyt2022123.

[75] Silva EA. Digital transformation and knowledge management: relationships in scientific production. En: Rodrigues Dias TM, editor. Advanced Notes in Information Science, vol. 2, ColNes Publishing; 2022. https://doi.org/10.47909/anis.978-9916-9760-3-6.107.

[76] Silva Júnior EMD, Dutra ML. A roadmap toward the automatic composition of systematic literature reviews. Iberoamerican Journal of Science Measurement and Communication 2021;1:1-22. https://doi.org/10.47909/ijsmc.52.

[77] Araujo-Inastrilla CR, Vitón-Castillo AA. Blockchain in health sciences: Research trends in Scopus. Iberoamerican Journal of Science Measurement and Communication 2023;3. https://doi.org/10.47909/ijsmc.56.

[78] Gontijo MCA, Hamanaka RY, De Araujo RF. Research data management: a bibliometric and altmetric study based on Dimensions. Iberoamerican Journal of Science Measurement and Communication 2021;1:1-19. https://doi.org/10.47909/ijsmc.120.

[79] Ledesma F, Malave González BE. Patterns of scientific communication on E-commerce: a bibliometric study in the Scopus database. Reg Cient 2022:202214. https://doi.org/10.58763/rc202214.

[80] Castillo VS, Cano CAG, Gonzalez-Argote J. Telemedicine and mHealth Applications for Health Monitoring in Rural Communities in Colombia: A Systematic Review. EAI Endorsed Transactions on Pervasive Health and Technology 2023;9.

[81] Murgas Téllez B, Henao-Pérez AA, Guzmán Acuña L. Real Options and their application in renewable energy projects. State-of-the-art review. Reg Cient 2023:202349. https://doi.org/10.58763/rc202349.

[82] Valencia-Contrera M, Rivera-Rojas F, Villa-Velásquez J, Ardiles-Irarrazabal R, Febré N, Valenzuela-Suazo S. Methodological strategies for the generation of conceptual models in nursing. Salud Cienc Tecnol 2023:315. https://doi.org/10.56294/saludcyt2023315.

[83] Castillo-Gonzalez W, Piñera-Castro HJ, Vitón-Castillo AA, Lepez CO, Gonzalez-Argote J, Bonardi MC, et al. The 100 most cited articles on wearable technology in the area of Medical Informatics: A bibliometric analysis using Web of Science. EAI Endorsed Transactions on Pervasive Health and Technology 2022;8:e5-e5.

[84] Petrona Aguirre JI, Marsollier R, Vecino J. Teaching Burnout: a conceptual cartographic review. AWARI 2020;1:e021. https://doi.org/10.47909/awari.82.

[85] Witt AS, Fabiano Couto Corrêa Da Silva S. Analysis of citizen science in Brazil: A study of the projects registered in the Civis platform. Iberoamerican Journal of Science Measurement and Communication 2022;2. https://doi.org/10.47909/ijsmc.162.

[86] Guardado RT, Carmona EA, Verver Y Vargas HGL, Hernández ISJ, Martínez NGP, Trejo BYV. Opportunities and applications of smart contracts: A vision from the business, academic and scientific literature. Iberoamerican Journal of Science Measurement and Communication 2022;2. https://doi.org/10.47909/ijsmc.v2i2.32.

[87] Shettar I, Hadagali GS, Timanaykar R. Scientometric mapping of global publications on pulmonary embolism in Covid-19 research. Iberoamerican Journal of Science Measurement and Communication 2023;3. https://doi.org/10.47909/ijsmc.524.

[88] Oviedo A, Gonzalez-Argote J. Factores asociados con la resistencia a la implementación de la historia clínica electrónica. Revista Cubana de Medicina Militar 2022; 51 (4):2094.

[89] Adegoriola MI, Lai JHK, Chan EH, Darko A. Heritage building maintenance management (HBMM): A bibliometric-qualitative analysis of literature. Journal of Building Engineering 2021;42:102416. https://doi.org/10.1016/j.jobe.2021.102416.

[90] Machuca-Contreras F, Canova-Barrios C, Castro MF. An approach to the concepts of radical, incremental and disruptive innovation in organizations. Reg Cient 2023:202324. https://doi.org/10.58763/rc202324.

[91] De Sousa RPM, Shintaku M. Data privacy policy: relevant observations for its implementation. En: Rodrigues Dias TM, editor. Advanced Notes in Information Science, vol. 2, ColNes Publishing; 2022. https://doi.org/10.47909/anis.978-9916-9760-3-6.112.

[92] Mae Samuel A, Garcia-Constantino M. User-centred prototype to support wellbeing and isolation of software developers using smartwatches. En: Huisa Veria E, editor. Advanced Notes in Information Science, vol. 1, ColNes Publishing; 2022. https://doi.org/10.47909/anis.978-9916-9760-0-5.125.

[93] Amaral ED, De Araújo GM. Dataset extraction from advertising marketplaces: experiences with Facebook, Olx, and Mercadolivre. En: Rodrigues Dias TM, editor. Advanced Notes in Information Science, vol. 2, ColNes Publishing; 2022. https://doi.org/10.47909/anis.978-9916-9760-3-6.103.

[94] Huifeng W, Kadry SN, Raj ED. Continuous health monitoring of sportsperson using IoT devices based wearable technology. Computer Communications 2020;160:588-95. https://doi.org/10.1016/j.comcom.2020.04.025.

[95] Xiao N, Yu W, Han X. Wearable heart rate monitoring intelligent sports bracelet based on Internet of things. Measurement 2020;164:108102. https://doi.org/10.1016/j.measurement.2020.108102.