



Towards a Smart Healthcare System for Non-Communicable Diseases (NCDs) Management: A Bibliometric Analysis

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Abstract. The World Health Organization has chastised the persistence and gradual progression of non-communicable diseases (NCDs) and their impact on human nature, which necessitates an urgent review of measures to combat them. This study employed a bibliometric analysis to comprehensively review and synthesise the body of knowledge on smart healthcare systems for NCD management. The study identified major developments, knowledge gaps, and major contributors to the research field. Biblioshiny and VOSviewer software were used to retrieve data from the Scopus database, and performance analysis and science mapping were used to analyse the data. The search string used was (“Smart Healthcare” OR “Smart Healthcare System” OR “Intelligent Healthcare” OR “Healthcare IoT”) AND (“Non-Communicable Disease” OR “NCDs” OR “Chronic Disease” OR “Chronic Illness”) AND (“Management” OR “Disease Management” OR “Healthcare Management” OR “Patient Management”). The results revealed that the number of articles on smart healthcare systems for NCD management increased exponentially between 2007 and 2023, signifying a rising need for technology improvements in combating NCDs. Keywords that emerged include machine learning, remote sensing, Internet of Things, wearable devices, and mobile health. These terms are increasingly being used within healthcare and reflect a multi-disciplinary approach to the management of NCDs. The study recommends that given the substantial co-authorship, more interdisciplinary research can be used to explore underrepresented topics or approaches.

Keyword: Smart Healthcare · Non-Communicable Diseases (NCDs) · Internet of Things (IoT) · Artificial Intelligence (AI)

1 Introduction and Background

According to the World Health Organization (WHO), non-communicable diseases (NCDs) are chronic conditions that persist over an extended period and generally exhibit a gradual progression [1, 2]. There are four main categories of NCDs: malignancies (lung cancer and colorectal cancer), diabetes mellitus (DM), chronic respiratory conditions

(asthma and chronic obstructive pulmonary disease), and cardio-vascular conditions (stroke, heart attacks and hypertension) [3]. NCDs are among the top causes of mortality [4]. In fact, seven out of 10 deaths worldwide are caused by NCDs [5, 6]. This is further amplified by global statistics that point to NCDs being the cause of 74% of deaths worldwide and being a major cause of disability and loss of productivity [2]. By 2030, it is expected that 52 million people will die from NCDs, and low - and middle-income countries will account for 80% of these deaths [7]. In addition, these countries are increasingly carrying the burden associated with the economic and health expenses related to NCDs [8]. This necessitates an urgent review of measures intended to combat NCDs.

Although NCDs cannot always be prevented, several actions may lower the chances of contracting them. Therefore, it is imperative to take preventative measures as a way of reducing the impact of NCDs [8]. The majority (80%) of risk factors for early cardiovascular disease, stroke, and diabetes can be controlled by the dissemination of knowledge (awareness) on risk factors [9, 10]. According to Chen et al., these risk factors include smoking, abusing alcohol, eating poorly, a lack of exercise, being overweight or obese, and having elevated blood pressure, high blood sugar levels, and high cholesterol levels [9]. If NCDs can be identified and predicted in their early stages, healthcare interventions can be implemented to minimize their adverse effects on patients [10]. An example of tools that can be used to predict the potential of contracting NCDs includes wearable sensors for health monitoring, activity tracking, disorder prediction, treatment evaluation, home rehabilitation, and safety monitoring, to name a few [11]. In addition, the use of mobile health (mHealth) is considered one of the solutions to eradicating the surge of NCDs [12]. According to Hsu, Alavi and Dong, mHealth entails the use of smartphones, patient monitoring programs, and other wireless equipment as part of healthcare interventions to treat a variety of medical and public health disorders. mHealth can also be used for self-management through smart healthcare [13]. Self-management through smart healthcare comprises a collection of tools that a person employs daily to control a chronic condition like NCDs and encourage recovery [14].

Traditional healthcare systems are challenged by scarce resources and rising service demand and smart healthcare systems are poised to be a viable response to these problems [15]. By utilizing cutting-edge technologies and creative strategies, smart healthcare seeks to improve healthcare in terms of intelligence (data gathering), effectiveness, and sustainability [16]. By utilizing the Internet of Things (IoT), artificial intelligence (AI), cloud computing, and big data, smart healthcare can transform the healthcare system to make it more personalized, effective, and convenient [17].

Therefore, the purpose of this study was to employ a bibliometric analysis approach to comprehensively review and synthesise the body of knowledge on smart healthcare systems for the management of NCDs and to identify major developments, knowledge gaps, and major contributors to the research field. Thus, the objectives of this study were:

- i. To determine the key themes in the literature that relate to the application of smart healthcare systems for the management of NCDs.
- ii. To identify the most influential journals and authors related to research on smart healthcare systems for the management of NCDs.

- iii. To evaluate, using citation analysis, the significance of important publications and authors related to research on smart healthcare systems for the management of NCDs.
- iv. To identify gaps within the current body of knowledge related to research on smart healthcare systems in NCD management and propose future studies.
- v. To determine the geographical dispersion of research endeavours in the application of smart healthcare systems to manage NCDs.

2 Methodology

Bibliometric analysis is a quantitative tool for analyzing research trends [18]. It was used in this study to assess the output of publications, research trends, and publishing trends on smart healthcare systems for NCD management. Biblioshiny and VOSviewer software were used to retrieve data from the Scopus database on the 12th of September 2023. The period under study was 2007 to 2023. Performance analysis (publication trends, top contributing authors, top contributing journals, top contributing institutions and top contributing countries) and science mapping (relationships, co-occurrences, network analysis) were used in the bibliometric analysis [19]. The search string used to search for articles from the Scopus database was: ALL (“Smart Healthcare” OR “Smart Healthcare System” OR “Intelligent Healthcare” OR “Healthcare IoT”) AND (“Non-Communicable Disease” OR “NCDs” OR “Chronic Disease” OR “Chronic Illness”) AND (“Management” OR “Disease Management” OR “Healthcare Management” OR “Patient Management”).

3 Results

A total of 1235 original documents (journal articles, conference papers, review articles, book chapters, books, editorials, notes, retracted, letters and surveys) were retrieved from the Scopus online database for the period 2007 to 2023. The documents revealed 691 sources, 6 432 keywords and 3251 author’s keywords. A total of 4522 authors contributed to the documents. The collaboration index was 4.54, indicating a high degree of collaboration among the documents as depicted in Table 1.

Table 1. Basic information on the selected articles

Database: Scopus
Timespan: 2007 to 2023
Annual growth rate: 36.34%
Authors: 4522
Single-authored documents: 56
Average of co-authors per document: 4.54
International collaboration (in percentage): 34.98%
Distribution by document type: Journals (613), conference articles (237), review articles (193), book chapters (161), books (16), editorials (5), notes (5), retracted (3), letter (1), and survey (1)

The retrieved documents were published in 495 diverse sources. The top 20 sources are depicted in Table 2. The journal IEEE Access had the highest total citations (TC) ($n = 2300$) with 41 publications (NP = 41) on smart healthcare systems for NCDs management. The journal also had the highest h-index and g-index (see Table 2).

Table 2. Source local impact

Element	h_index	g_index	m_index	TC	NP
IEEE Access	21	41	3,00	2300	41
Journal of Medical Systems	10	13	1,00	839	13
Sensors	10	15	3,33	245	26
Sensors (Switzerland)	8	9	0,80	1118	9
Journal of Ambient Intelligence and Humanized Computing	7	12	0,64	252	12
Future Generation Computer Systems	6	6	0,60	505	6
IEEE Internet of Things Journal	6	7	1,20	299	7
International Journal of Environmental Research and Public Health	6	10	1,50	118	18
Journal of Biomedical Informatics	6	7	0,67	281	7
Lecture Notes in Computer Science (including subseries Lecture Notes in AI and Bioinformatics)	6	10	0,35	113	19
Soft computing	6	7	0,75	111	7
Wireless Personal Communications	6	10	0,75	217	10
Cluster Computing	5	6	0,56	162	6
Healthcare (Switzerland)	5	7	1,67	66	15
International Journal of Medical Informatics	5	5	1,00	85	5
Journal of Healthcare Engineering	5	7	1,67	101	7
Journal of Medical Internet Research	5	8	1,25	118	8
Journal of Network and Computer Applications	5	6	0,83	527	6
Wireless Communications and Mobile Computing	5	7	0,63	71	7
Computational Intelligence and Neuroscience	4	9	1,33	109	9

The authors Chung K and Wu J had 11 publications each, with the former having a superior h-index and the g-index, and 324 total citations (TC). In contrast, Wu J had 7 and 10 for the h-index and g-index respectively and 110 total citations. Zaidan BB had the highest TC with nine publications, resulting in an h-index of 7. Table 3 depicts the top 20 authors with the highest impact.

Table 3. Author's local impact

Element	h_index	g_index	m_index	TC	NP
Chung K	8	11	0,89	324	11
Albahri AS	7	7	1,17	512	7
Albahri OS	7	7	1,17	512	7
Wu J	7	10	2,33	110	11
Zaidan AA	7	7	1,17	512	7
Zaidan BB	7	9	1,17	516	9
Alsalem MA	6	6	1,00	376	6
Fogliatto FS	6	7	1,50	193	7
Tortorella GL	6	7	1,50	193	7
Gou F	5	8	1,67	71	8
Kumar A	5	9	0,83	200	9
Tang H	5	6	1,67	147	6
Zhu J	5	6	0,50	45	8
Bhatt V	4	5	1,00	26	5
Chakraborty S	4	5	1,00	29	6
Clark CCT	4	6	1,00	60	21
Elhoseny M	4	4	0,80	130	4
Gupta A	4	7	0,80	56	7
Jara AJ	4	4	0,27	178	4
Kumar R	4	7	0,80	94	7

Figure 1 shows the country's rate of production in terms of publications on smart healthcare systems for NCD management. The period for this exponential growth spans from 2007 to 2023. Although all the top countries (India, China, USA, United Kingdom, Iran, and South Korea) experienced an exponential growth rate, India's rate of growth in terms of production surpassed 800 articles. China also experienced considerable growth in terms of production. This is probably the reason why China and India had the highest number of total citations (3187 and 1532 respectively). Table 4 depicts the most cited countries.

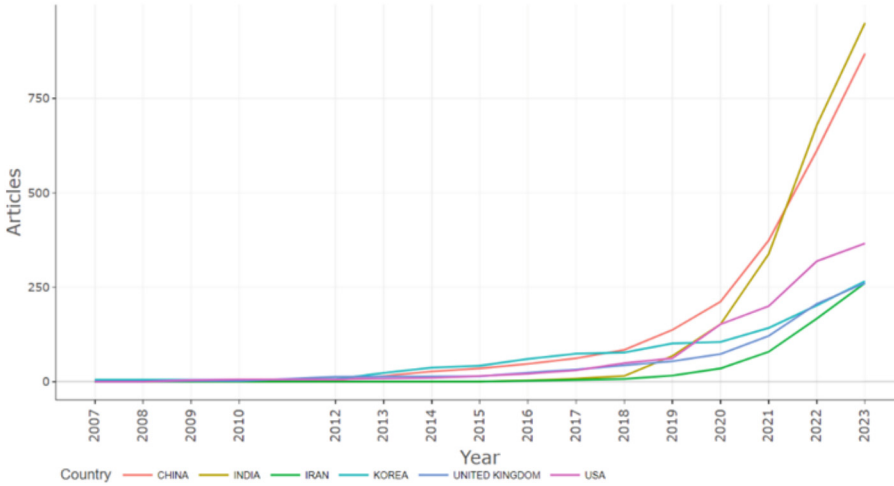


Fig. 1. Country production

Table 4. Most cited countries

Country	TC	Average article citations
China	3187	18,3
India	1532	9,6
USA	1440	28,2
South Korea	1084	17,2
Canada	1071	51
Australia	950	45,2
Malaysia	802	33,4
Iran	793	16,5
Italy	581	23,2
United Kingdom	557	15,5
Saudi Arabia	491	18,9
Egypt	428	32,9
Spain	380	18,1
Brazil	368	28,3
New Zealand	297	74,2
Croatia	293	146,5
Thailand	195	195

(continued)

Table 4. (continued)

Country	TC	Average article citations
Bangladesh	192	24
Germany	168	12
Iraq	154	30,8

Table 5 depicts the most globally cited articles. The most cited article is titled *Wearable Sensors for Remote Health Monitoring* and was authored by Majumder, S., Mondal, T., and Deen, M.J. in 2017. The article was published in the journal *Sensors* and received a record 720 citations. Amongst the top 20 publishers, *IEEE Access* published the highest number of articles related to smart healthcare in the context of NCDs with 4 articles (20%).

Table 5. Top 20 most globally cited articles

Author(S)	Publisher	Article Title	TC	TC/Year
Majumder et al. (2017) [1]	Sensors	Wearable Sensors for Remote Health Monitoring	720	102,86
Baker et al. (2017) [20]	IEEE Access	Internet of Things for Smart Healthcare: Technologies, Challenges, and Opportunities	678	96,86
Yin et al. (2016) [21]	Journal of Industrial Information Integration	The Internet of Things in Healthcare: An Overview	534	66,75
Chen et al. (2016) [22]	Mobile Networks and Applications	Smart Clothing: Connecting Humans with Clouds and Big Data for Sustainable Health Monitoring	314	39,25
Nizetic et al. (2020) [23]	Journal of Cleaner Production	Internet of Things (IoT): Opportunities, Issues, and Challenges Towards a Smart and Sustainable Future	293	73,25
Liu et al. (2019) [24]	IEEE Access	A Novel Cloud-Based Framework for the Elderly Healthcare Services Using Digital Twin	279	55,80

(continued)

Table 5. (continued)

Author(S)	Publisher	Article Title	TC	TC/Year
Qi et al. (2017) [25]	Pervasive and Mobile Computing	Advanced Internet of Things for Personalised Healthcare Systems: A survey	279	39,86
Tian et al. (2019) [26]	Global Health Journal	Smart Healthcare: Making Medical Care More Intelligent	278	55,60
Ghamari et al. (2016) [27]	Sensors	A Survey on Wireless Body Area Networks for Healthcare Systems in Residential Environments	228	28,50
Nweke et al. (2019) [28]	Information Fusion	Data Fusion and Multiple Classifier Systems for Human Activity Detection and Health Monitoring: Review and Open Research Directions	225	45,00
He et al. (2021) [29]	International Journal of Information Management	Information Technology Solutions, Challenges, and Suggestions for Tackling the COVID-19 Pandemic	215	71,67
Chen et al. (2018) [30]	Future Generation Computer Systems	Edge Cognitive Computing Based Smart Healthcare System	206	34,33
Aceto et al. (2018) [31]	Journal of Network and Computer Applications	The Role of Information and Communication Technologies in Healthcare: Taxonomies, Perspectives and Challenges	206	34,33
Chen et al. (2022) [32]	Chemical Reviews	Electronic Textiles for Wearable Point-of-Care Systems	201	100,50
Dey et al. (2017) [33]	IEEE Transactions on Consumer Electronics	Developing Residential Wireless Sensor Networks for ECG Healthcare Monitoring	201	28,71
Pal et al. (2018) [34]	IEEE Access	Internet-of-Things and Smart Homes for Elderly Healthcare: An End User Perspective	195	32,50

(continued)

IoT-based systems in the form of wearables for monitoring blood pressure, vital signs, and oxygen levels within blood. The high number of citations in this article signifies the relevance of technological interventions in mitigating NCDs within healthcare. Figure 4 depicts the co-citations analysis.

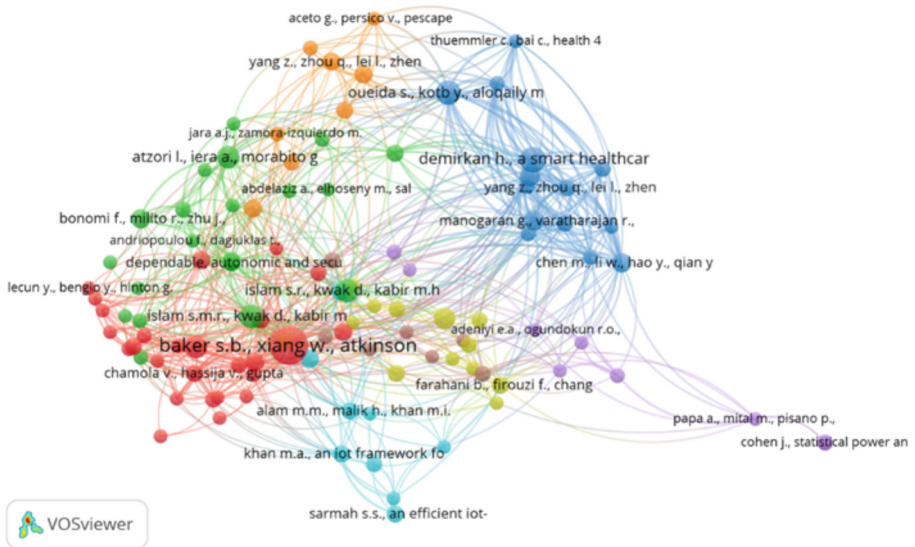


Fig. 4. The co-citation analysis

VOSviewer was also used for the bibliometric coupling of sources. For each of the 43 sources selected, the total strength of the bibliometric coupling links with other authors was calculated and the sources with the greatest link strength were selected. True to what has been confirmed so far in this study, *IEEE Access* has the highest number of documents ($n = 41$), the highest number of citations ($n = 2300$) and the strongest total



Fig. 5. Bibliometric coupling of sources

link strength (n = 243). Other sources within the top five were *Sensors*, *Healthcare* (Switzerland), *Electronics* (Switzerland) and *Diagnostics*, as summarised in Fig. 5.

Using the criterion of at least five sources per country, a total of 60 countries were loaded from a possible 113 countries, and the total strength of the bibliometric coupling links with other countries was calculated. India had the highest value in terms of links (n = 59), the highest total link strength (n = 20163), and the highest number of documents (n = 312). Other countries within the top five included the United Kingdom, Australia, China, and the USA. This is depicted in Fig. 6.

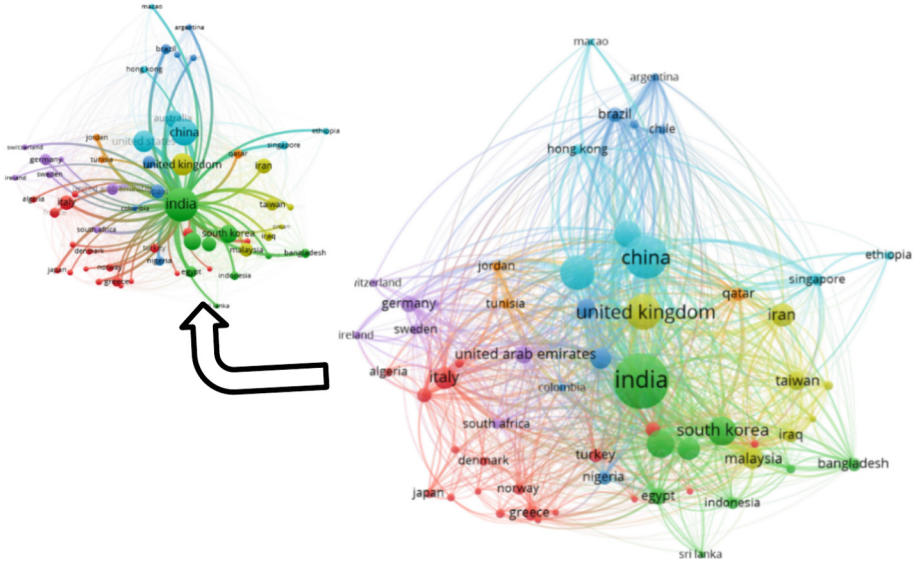


Fig. 6. Bibliometric coupling of countries.

A three-field plot analysis was performed using Biblioshiny to classify authors, their affiliations, and the most frequently used keywords and this is depicted in Fig. 7. The relationships between the top 20 frequently used keywords, top 20 institutions and top 20 authors are summarised by the three-field plot (Sankey diagram). “Human”, “humans”, “artificial intelligence”, “female”, “healthcare”, “Internet of Things”, “telemedicine”, “chronic diseases” and “aged” are some of the most used keywords by top institutions that include Coventry University (United Kingdom), Central South University (China), Universiti Pendidikan Sultan Idris (Malaysia), Huazhong University of Science and Technology (China) and University of Melbourne (Australia). The authors who were very active within the institutions include Wu J., Chen M., Wang Y., Wang X. and Zhang Y.

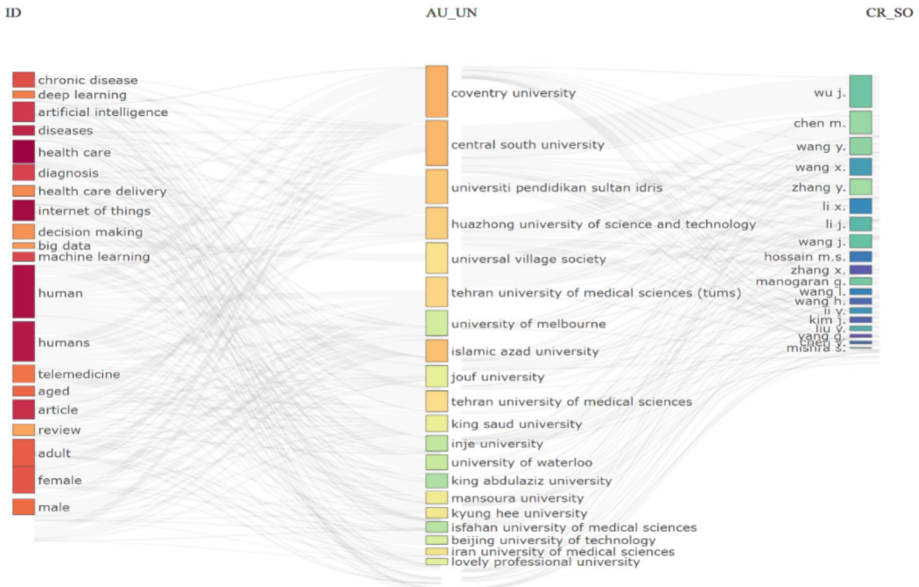


Fig. 7. The Three-field plot for keywords, affiliations, and authors

4 Discussion

The number of articles on smart healthcare systems for NCD management increased exponentially between 2007 to 2023, as is evidenced from this study. This can signify a rising need for technology improvements to combat NCDs. China has witnessed an upsurge in a variety of NCDs and various stakeholders have taken a strong stance and effort to control them [39]. Research by [40] posits that NCDs have been China's biggest, yet neglected, health challenge. This is why China, according to Wu *et al.*, has been increasing its budget yearly to help fight the challenge of NCDs [41]. It is not surprising, therefore, that China reports a high number of authors who publish research related to smart healthcare systems and NCD management.

An analysis of the publications on smart healthcare systems for NCD management reflects *IEEE Access* as the most significant publisher in terms of the number of citations and publications. The *IEEE Access* journal is a reputable, multi-disciplinary source for innovative research in smart healthcare systems, based on its scope on its website [42].

The article by [1], titled “*Wearable Sensors for Remote Health Monitoring*” is the most cited article, based on the results depicted in this study. The article described a simple yet cost-effective system prioritising the healthcare welfare of the elderly. It gained much visibility and audience because of its emphasis on remote healthcare monitoring using IoT-based systems [43, 44]. According to Rejeb *et al.*, IoT systems have advanced, opening up new possibilities and solutions for healthcare services, including remote patient monitoring and treatment [43].

This study also identified the top search terms and popular subjects related to smart healthcare systems for NCD management. The top five most used keywords were

"human," "healthcare," "humans," "Internet of Things," and "machine learning." The various forms of NCDs affecting humans are now a cause for concern. Multiple forms of remedial solutions include the use of the IoT and machine learning. As alluded to by [44], the IoT can be integrated with machine learning to enhance the provision of healthcare in terms of decision-making, treatment and diagnosis.

The study also showed a high co-authorship rate, which is indicative of the collaborative nature of research investigating the nexus between smart healthcare and NCD management. This can be a sign of a diversified research strategy since scientific networking is a defining feature of modern academic research [45]. Another study [46] also added that researchers are now part of teams that combine complementary abilities and multidisciplinary approaches to work towards common goals rather than acting independently.

4.1 NCDs Management Using Smart Healthcare Within the African Context

The importance of our study is magnified when viewed in the context of Africa, where NCDs pose unique challenges and opportunities. NCDs are increasingly prevalent in Africa, with a shift from infectious to chronic diseases occurring rapidly [47]. This emphasises the need for innovative healthcare solutions. However, implementing smart healthcare systems in Africa faces obstacles such as inadequate infrastructure, economic challenges, and the glaring problem of the digital divide [48]. Despite these challenges, the continent is expanding mobile network coverage and Internet accessibility, and this offers unprecedented prospects for digital health interventions [49]. Recent initiatives like the Digital Transformation Strategy for Africa (2020–2030) by the African Union demonstrate a commitment to harness digital technologies in healthcare [50]. To effectively utilise smart healthcare technologies for managing NCDs in Africa, it is essential to develop strategies that consider local healthcare systems, cultural factors, and technological infrastructure [51]. These strategies should focus on improving accessibility and efficiency in healthcare delivery while ultimately striving to enhance health outcomes within the African setting.

4.2 Theoretical Contributions

The present study makes several noteworthy theoretical contributions to the field of smart healthcare systems and the management of NCDs:

- Through the execution of a comprehensive bibliometric analysis, this study expands the comprehension of the development and status of smart healthcare technologies within the context of NCD management.
- The findings shed light on the interdisciplinary nature of research in smart healthcare, demonstrating how collaborations across diverse fields can enhance the examination and application of technologies in healthcare.
- The study enriches the existing body of theory by showcasing the integration of emerging technologies such as the IoT, machine learning, and wearable devices in healthcare, presenting a fresh perspective on technology-driven solutions for healthcare.

4.3 Theoretical Implications

The theoretical implications of this study are threefold:

- The findings of this study have the potential to guide future research agendas by identifying gaps and trends in the literature, particularly about the application of smart technologies in the management of NCDs.
- The bibliometric approach employed in this study can serve as a model for future research in similar domains, promoting the adoption of data-driven methodologies to comprehend intricate healthcare challenges.
- The research contributes to the theoretical understanding of how emerging technologies can be effectively incorporated into healthcare systems, especially in the management of NCDs.

4.4 Practical Implications

The practical implications of this study hold great significance for various stakeholders:

- The study offers valuable insights into the effective implementation of smart technologies in healthcare settings, emphasising the necessity for policies that support the integration of these technologies in the management of NCDs.
- The findings can inform the development of novel technologies and research initiatives, with a focus on areas that are presently underrepresented or possess substantial potential for enhancing the management of NCDs.
- The study's global perspective on smart healthcare systems provides valuable information for international health organisations and initiatives aiming to combat NCDs through technological advancements.

4.5 Limitations

The bibliometric approach employed in this study, although comprehensive, is subject to the following limitations:

- The use of Scopus as the exclusive database may have resulted in the confinement of the literature surveyed.
- Furthermore, the search strategy, which relied on keywords, and although extensive, may not have encompassed all critical studies, particularly those using diverse terminologies or emerging technologies that have not yet gained widespread recognition in the field.

4.6 Recommendations

Based on the findings of this study, we propose the following recommendations:

- There should be encouragement for more profound interdisciplinary research endeavours, which would allow for the exploration of areas that have been underrepresented and the integration of diverse areas of expertise.
- Emphasis on policy: Policymakers should strive to achieve a balance in the research landscape, with particular attention given to regions and countries that have not been adequately represented in smart healthcare research.

- The scope of impactful research should be broadened beyond dominant journals such as *IEEE Access*, encompassing a wider array of publications. This expansion would foster a research environment that is more inclusive and comprehensive.

5 Conclusion

This article offers a well-organised and perceptive bibliometric analysis that adds to the body of knowledge presently available on smart healthcare systems for NCD management. The various forms of NCDs affecting humans are now a cause for concern. The results reflect the global stance of many countries where a large portion of their budgets is also invested in combating NCDs. This could also perhaps be the reason why many authors, many institutions and many countries have increased their focus and output in formulating various ways of managing NCDs. The study points to the increase in the number of articles on smart healthcare systems for NCD management, which are receiving convincing citations. Fundamentally, technologies like the IoT, machine learning, remote sensing, wearable devices, and mobile health are increasingly being used within healthcare and reflect a multidisciplinary approach to the management of NCDs. The field of smart healthcare systems for NCD management is characterised by its high co-authorship.

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