Health informatics publication trends in Saudi Arabia: a bibliometric analysis over the last twenty-four years

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Objective: Understanding health informatics (HI) publication trends in Saudi Arabia may serve as a framework for future research efforts and contribute toward meeting national “e-Health” goals. The authors’ intention was to understand the state of the HI field in Saudi Arabia by exploring publication trends and their alignment with national goals.

Methods: A scoping review was performed to identify HI publications from Saudi Arabia in PubMed, Embase, and Web of Science. We analyzed publication trends based on topics, keywords, and how they align with the Ministry of Health’s (MOH’s) “digital health journey” framework.

Results: The total number of publications included was 242. We found 1 (0.4%) publication in 1995–1999, 11 (4.5%) publications in 2000–2009, and 230 (95.0%) publications in 2010–2019. We categorized publications into 3 main HI fields and 4 subfields: 73.1% (n = 177) of publications were in clinical informatics (85.1%, n = 151 medical informatics; 5.6%, n = 10 pharmacy informatics; 6.8%, n = 12 nursing informatics; 2.3%, n = 4 dental informatics); 22.3% (n = 54) were in consumer health informatics; and 4.5% (n = 11) were in public health informatics. The most common keyword was “medical informatics” (21.5%, n = 52). MOH framework–based analysis showed that most publications were categorized as “digitally enabled care” and “digital health foundations.”

Conclusions: The years of 2000–2009 may be seen as an infancy stage of the HI field in Saudi Arabia. Exploring how the Saudi Arabian MOH’s e-Health initiatives may influence research is valuable for advancing the field. Data exchange and interoperability, artificial intelligence, and intelligent health enterprises might be future research directions in Saudi Arabia.

Keywords: biomedical informatics; health informatics; clinical informatics; consumer health informatics; public health informatics; bibliometric analysis

INTRODUCTION

Biomedical informatics (BMI) is defined as “the interdisciplinary field that studies and pursues the effective uses of biomedical data, information, and knowledge for scientific inquiry, problem-solving, and decision making, motivated by efforts to improve human health” [1]. BMI is a fast-evolving field and the core scientific discipline supporting both applied research and practice, which includes health informatics (HI) and subfields [1]. Its interdisciplinary nature and its relevance to health care advancement are major contributing factors [2, 3].

Literature trends and bibliometric analysis of published research help quantify insights into the current and future trends of the field, research efforts, and educational programs development [4–6]. During the past five years, research efforts examining publication trends in the HI field show great attention to the areas of clinical informatics, consumer health informatics, and mobile health [7, 8]. This focus may be due to the increased use of smartphones and other technologies [7] and is expected to continue growing in the future [8]. In addition, many researchers have explored how specific policies and regulations may affect the advancement of the field. For example, in the United States, key findings of the American Medical Informatics Association’s (AMIA’s) review on clinical and consumer informatics topics show that newly established US policies for electronic health record (EHR) implementation and evaluation introduce new challenges in health care, such as data interoperability, the impact of decision support systems,
predictive models and their utilization, mobile applications and EHR systems integration, and the early stages of interactive natural language systems development [9].

In Saudi Arabia, the first institution obtained access to the Internet in 1993 [10]. At that time, the national health reform committee identified a lack of HI applications and information systems as a challenge within the health sector. Accordingly, a task force was developed in 2002 to build a national EHR and to expand electronic health services, including telemedicine. As a result, the Saudi Association for Health Informatics [11], the first official HI association in the country, was established in 2005 [12], and the Ministry of Health (MOH), guided by the country’s 2030 vision, launched several initiatives in 2010 to support the development of a national “e-Health” strategy, which included a ten-year roadmap based on patient-centric care [13].

The MOH positions e-Health as the primary transformative and enabler agent, with the primary goal of the e-Health strategy being to provide care for patients, connect providers, measure performance, and transform health care delivery to standardized care [13]. Guiding and supporting research was specifically stated as one of the e-Health objectives [14], with the aim of improving health care through utilization of information technology and digital transformation [15]. The MOH also developed a “digital health strategy” highlighting the need for rapid digital change and reinvention [14]. Examples of projects that have been initialized or completed as part of the e-Health initiative are a medical records improvement program, referral system (Ehalty), unified portal of health services, health electronic surveillance network, poison control e-system (Awtar), neonatal protection system, hospitals’ serious incidents registration e-system, and premarital screening system [16, 17]. These national efforts and the MOH’s e-Health initiative have played a big role in the evolution of the HI field in Saudi Arabia during the last decade.

Understanding current HI publication trends in Saudi Arabia may contribute to meeting national e-Health goals. Publications in scientific journals offer insights into topics and trends in HI research [2, 3, 18] and can identify gaps in research that support the advancement of HI [3]. To the best of our knowledge, no studies have explored HI research trends, particularly in Saudi Arabia. As the role of governing policies on the future of HI requires exploration through published literature and open discussions by experts in the field of HI [9], the authors aimed to explore trends in HI research in Saudi Arabia and understand how these publications might be aligned with the MOH’s digital health plans. Ultimately, we intend to understand the past, current, and future state of the HI field, which includes clinical informatics, consumer health informatics, and public health informatics.

METHODS

The Ministry of Health’s (MOH’s) “e-Health” strategy overview

In 2010, the MOH initiated the 2010–2020 roadmap for the national e-Health strategy, separated into two five-year phases, which was launched in early 2011 [13, 14]. The evolution of digital health first started in 2010 with some standalone systems that had limited functionalities and lacked interoperability [14]. The MOH’s objective for the national e-Health system is to improve individuals’ personal experiences, increase efficiency and performance, improve health outcomes and equity, enable health providers to deliver better services, and provide evidence for policy, research, and planning [13, 14]. To measure the country’s digital capabilities as part of the national e-Health strategy, the MOH developed a framework called the “digital health journey,” which consists of six levels: (1) digital health foundations; (2) digitally enabled care (e.g., EHRs and decision support); (3) smart care (e.g., precision medicine, artificial intelligence, robotics, and medical printing); (4) care anywhere (e.g., virtual care, connected care teams, and connected homes); (5) empowered care (e.g., models of care, patient experience, and personal health data); and (6) intelligent health enterprises (e.g., seamless financing; data-driven, value-based, accountable care; and end-to-end systems) [14]. We used the six levels in this “digital health journey” as a framework for our study to categorize HI publication trends.

Search strategy

We conducted a scoping review to identify publications within the field of HI using three databases: PubMed, Embase, and Web of Science (WOS). A librarian, who is an expert researcher in the field, was consulted for search keywords and database selection. The search queries for each HI discipline (supplemental Appendix A) were based on the AMIA Board white paper for defining the BMI field [1]. All search queries were accompanied by “Saudi Arabia” or “Saudi” to limit our results to publications written by authors affiliated with Saudi institutions. We included all publications until December 31, 2019.

Screening and study selection

Figure 1 shows our search and screening process. Database searching yielded a total of 1,152 records. After duplicate records were removed, a total of 900 records were screened. Three BMI experts performed the title and abstract screening using Rayyan, a web application that facilitates record screening for systematic reviews [19]. The records were divided into three subsets, with each subset assigned to two reviewers for independent screening. Discrepancies were resolved by the third reviewer. The inclusion criteria were (1) first author from or study location in Saudi Arabia and (2) an HI-related
topic. The exclusion criteria were (1) records without abstracts, (2) proposals, (3) abstract language not Arabic or English, and (4) non-HI topics, including bioinformatics, structural (i.e., imaging) informatics, and informatics in translational science (i.e., translational bioinformatics and clinical research informatics). Finally, records that were not accessible by our institutional access or the Saudi Digital Library were excluded. After removing a total of 658 records based on title and abstract screening, we included a final set of 242 records.

**Figure 1** Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) diagram

Data extraction and analysis

Each publication’s metadata were downloaded from PubMed, Embase, and WOS databases, which included abstract, publication year, journal name, and keywords (Medical Subject Headings [MeSH] from PubMed, Emtree from Embase, and authors’ keywords from WOS). We created a data extraction form using Google forms [20] for further analysis, which included the institutions/affiliations of all authors; whether first authors had Saudi affiliations; study location; data source (i.e., patients or medical data such as EHR data, surveys and/or questionnaires, interviews or focus groups, patient or disease registries, clinical or health care research datasets, and other data [e.g., social media]); publication type (e.g., research and applications, case reports, review, and other); type of methodology (i.e., qualitative, quantitative, mixed review, and other); and source of publication (i.e., journal, proceeding, and other) (supplemental Appendix B.).

Using titles and abstracts, we assigned HI fields and subfields to each publication, which consisted of clinical informatics (medical informatics, nursing informatics, pharmacy informatics, and dental informatics), public health informatics, and consumer health informatics. Publications were then categorized based on the MOH’s “digital health journey” framework [14]. Again, the set of records was divided into three subsets, with each subset assigned to two reviewers for independent categorization. Discrepancies were resolved by a third reviewer. We also performed descriptive analysis to identify trends in HI in Saudi Arabia between 1995 and 2019. We used Microsoft Excel and Tableau [21] for data analysis and visualization.

**RESULTS**

Analyses were based on 3 time periods: the first period was a 4-year interval from 1995 to 1999, and the subsequent 2 periods were 10-year intervals from 2000–2009 and 2010–2019. A total of 242 publications were included in our study. We found only 1 (0.4%) publication from 1995 to 1999, 11 (4.5%) from 2000–2009, and 230 (95%) from 2010–2019.

**Publication-based analysis**

Table 1 provides a descriptive summary of the included publications. There were 3 publication sources: 60.7% (n=147) journals, 38.8% (n=94) proceedings, and 0.4% (n=1) books. The most common publication type (74%, n=179) was “research and applications.” The study location was mostly in Saudi Arabia (57.5%, n=140). Other study locations included the United States (1.9%, n=3) [22–24], Malaysia (1.9%, n=3) [25–27], and Canada (0.8%, n=2) [28, 29]. The majority of publications (35.1%, n=85) used quantitative methods, and the minority of publications (9.1%, n=22) used mixed methods.
### Table 1: A descriptive summary of health informatics (HI) publications by Saudi-affiliated authors

| Source of publication | Publication type            | Study location    | Type of methodology | Total |
|-----------------------|----------------------------|-------------------|---------------------|-------|
| Journal               | Research and applications  | Saudi Arabia      | Quantitative 43 (17.77%) Qualitative 5 (2.07%) Mixed 8 (3.31%) Review 2 (0.83%) Other 14 (5.79%) | 118 (48.76%) |
|                        |                            | Malaysia          | 1 (0.41%) 1 (0.41%) — — — | — |
|                        |                            | Not specified     | 5 (2.07%) 3 (1.24%) 1 (0.41%) — | 20 (8.26%) |
|                        |                            | Canada            | 1 (0.41%) 1 (0.41%) — — — | — |
|                        |                            | Ethiopia          | 1 (0.41%) — — — — — | — |
|                        |                            | Iraq              | 1 (0.41%) — — — — — | — |
|                        |                            | Jordan            | 1 (0.41%) — — — — — | — |
|                        |                            | Madagascar        | 1 (0.41%) — — — — — | — |
|                        |                            | United States     | 1 (0.41%) — 1 (0.41%) — | 1 (0.41%) |
|                        |                            | Multiple countries| 5 (2.07%) — 1 (0.41%) — — — | — |
| Review                | Saudi Arabia              | — — 6 (2.84%) — — | 19 (7.85%) |
|                        | Not specified              | — — 13 (5.37%) — — | — |
| Case reports          | Saudi Arabia              | 2 (0.83%) — — — | 2 (0.83%) |
|                        | Multiple countries         | 1 (0.41%) — — — | 1 (0.41%) |
| Commentary            | Saudi Arabia              | — — 1 (0.41%) 2 (0.83%) — — | — |
|                        | Not specified              | — — 1 (0.41%) — — | — |
| Correspondence        | China                      | — — 1 (0.41%) 1 (0.41%) — — | — |
| Editorial             | Not specified              | — — 2 (0.83%) 2 (0.83%) — — | — |
| Perspective           | Saudi Arabia              | — — 1 (0.41%) 1 (0.41%) — — | — |
| Report                | Saudi Arabia              | — — 1 (0.41%) 1 (0.41%) — — | — |
| Proceeding            | Research and applications  | Saudi Arabia      | 12 (4.96%) 9 (3.72%) 7 (2.89%) 1 (0.41%) 9 (3.72%) | 61 (25.21%) |
|                        | Not specified              | 7 (2.89%) 2 (0.83%) — 1 (0.41%) 10 (4.13%) | — |
Table 1 A descriptive summary of health informatics (HI) publications by Saudi-affiliated authors (continued)

| Category          | Country/Region         | Publications | Percent |
|-------------------|------------------------|--------------|---------|
| Multiple countries|                        | 2            | 0.83%   |
| United Kingdom    |                        | 1            | 0.41%   |
| Saudi Arabia      |                        | 2            | 0.83%   |
| Not specified     |                        | 6            | 2.48%   |
| Review            | Saudi Arabia           | 2            | 0.83%   |
|                   | United Kingdom         | 1            | 0.41%   |
|                   | Not specified          | 6            | 2.48%   |
| Case reports      | Saudi Arabia           | 1            | 0.41%   |
|                   | Malaysia               | 1            | 0.41%   |
|                   | Not specified          | 2            | 0.83%   |
| Perspective       | Saudi Arabia           | 1            | 0.41%   |
|                   | Malaysia               | 1            | 0.41%   |
|                   | Not specified          | 5            | 2.07%   |
| Book Chapter      | Not specified          | 1            | 0.41%   |
| **Total**         |                        | 85           | 35.12%  |
|                   | 26                     | 10.74%       |
|                   | 22                     | 9.09%        |
|                   | 34                     | 14.05%       |
|                   | 75                     | 30.99%       |
|                   | 242                    | 100.00%      |
The first publication found was in 1995 (Figure 2). We observed a continuous increase in the number of publications from 2010–2016, when the highest peak (n=45, 18.6%) occurred. However, there was a decrease in the number of publications in 2017, 2018, and 2019. We found authors with Saudi affiliations as first authors in 203 (83.9%) publications. When we investigated the top institutions and cities for authors with Saudi affiliations (supplemental Appendix C), the institution with the most publications was King Saud bin Abdulaziz University for Health Sciences with 105 (43.4%) publications. The city of Riyadh had the highest number of contributing institutions’ publications.

We highlighted some major data sources that were used in HI publications. For publications in 1995–1999, there were no data sources found. For publications in 2000–2009, data sources used were surveys or questionnaire data [30], patient or medical data [31–33], clinical or health care research datasets [34], and patient or disease registries [35]. For publications in 2010–2019, more data sources were used, including surveys or questionnaire data [12, 24, 26, 36–96], interviews or focus groups [25, 27, 28, 37, 69, 94, 97–119], patient or medical data [23, 120–142], clinical or health care research datasets [23, 143–153], patient or disease registries [29, 67, 154, 155], and social media (Facebook [156, 157], Twitter [158, 159], Quora [22], and WhatsApp [160]) and new social media datasets [161].

Topic-based analysis

We investigated trends in research topics in publications based on HI fields and subfields (Figure 3). For 1995–1999, the first publication was in clinical informatics (subfield: medical informatics). For 2000–2009, all publications were in clinical informatics (subfield: medical informatics) except for 2007, when publications for consumer health informatics first appeared. For 2010–2019, there were new emerging trends in all HI fields and subfields within clinical informatics. Additionally, publications in public health informatics first appeared in 2013. Over the years, publication topics were mostly related to clinical informatics (73.1%, n=177) – including the subfields of medical informatics (85.3%, n=151), pharmacy informatics (5.6%, n=10), nursing informatics (6.8%, n=12), and dental informatics (2.3%, n=4) – with fewer publications related to consumer health informatics (22.3%, n=54) and public health informatics (4.5%, n=11).

Figure 2 Growth in the number of publications over years
**Keyword-based analysis**

To conduct keyword-based analysis, we extracted keywords from PubMed (MeSH keywords), Embase (Emtree keywords), and WOS (authors’ keywords). Non-HI related keywords were removed. The only publication in 1995–1999 [162] was associated with the keywords “medical informatics,” “hospital information systems,” and “information science.” For 2000–2009, new HI keywords emerged, including “electronic health record”; “Internet”; “doctor patient relationship”; “medical information”; “computer security”; “database management systems”; “registries”; “decision support systems, management”; “medical records systems, computerized”; “picture archiving and communication system”; “telemedicine”; “reminder systems”; “computer assisted diagnosis”; “prediction”; and “algorithm.” For 2010–2019, keywords emerged with new HI fields, such as “medical informatics,” “public health informatics,” “dental informatics,” “nursing informatics,” and “consumer health informatics.” There was a trend in patient-oriented keywords, such as “patient compliance,” “patient safety,” “patient care management,” “patient education as topic,” “patient satisfaction,” and “e-patients.” Keywords emerged in HI subdomains, such as “medical order entry systems,” “health information exchange,” “software,” “clinical pharmacy information systems,” “human computer interaction,” “sensitive health information,” and “systems integration.” Furthermore, keywords in data sciences, analytics, and technologies appeared, such as “data mining,” “data analysis,” “medical record linkage,” “mobile application,” “social media,” “ontology development,” “machine learning,” “big data,” “facial recognition,” “semantics,” “named entity recognition,” and “cloud computing.” Many of these keywords occurred only once in publications.

For the most frequent HI-relevant keywords in publications, Table 2 shows the top 30 keywords. “Medical informatics” was the earliest and most frequently occurring keyword (21.5%, n=52), appearing in every year except for 2002, 2007, and 2009. The “Internet” keyword emerged in year 2002. “Health informatics” first emerged in 2011 and then appeared yearly after 2013. The first occurrence of “social media” was in 2015. “Electronic medical record” and “telemedicine” first emerged in 2008. Considering these top 30 keywords, 2016 was the year with the highest frequency of HI keywords (25.2%, n=61).
Table 2  Top 30 keywords in publications

| Keyword                              | 1995 | 2002 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Grand total |
|--------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------------|
| Medical informatics                  | 1    | 1    | 2    | 1    | 1    | 3    | 2    | 2    | 6    | 6    | 9    | 6    | 3    | 9    | 52   |      |      |      |            |
| Internet                             |      | 1    |      | 1    | 1    | 4    | 2    | 2    | 1    | 4    | 2    | 2    | 1    |      | 20   |      |      |      |            |
| Health informatics                   |      |      | 1    |      | 1    | 3    | 2    | 3    | 4    | 2    | 4    |      |      |      | 20   |      |      |      |            |
| Social media                         |      |      |      |      |      | 4    | 6    | 5    | 2    | 2    |      |      |      |      |      |      |      |      |      | 19        |
| Electronic medical record            |      |      |      | 2    | 2    |      | 4    |      |      |      |      | 2    | 2    |    4  |      |      |      |      |      | 18        |
| Telemedicine                         |      |      |      |      | 1    |      | 2    |      |      |      |      | 4    |      |      |      |      |      |      |      |      | 17        |
| Medical order entry systems          |      |      |      |      |      | 1    | 2    | 3    | 1    | 2    |    2  | 2    | 1    | 1    |      |      |      |      |      | 13        |
| Health care quality                  |      |      |      |      |      |      | 1    |      |      |      |      |      |      |      |      |      |      |      |      | 13        |
| Electronic health records            |      |      |      |      |      |      |      | 2    | 1    | 4    |      |      |      |      |      |      |      |      |      | 13        |
| Electronic health record             |      |      |      |      |      |      |      |      |      |      |      |      |      | 3    |    4  |      |      |      |      | 13        |
| Medical information system           |      |      |      |      |      |      |      |      | 1    | 2    |      |      | 2    | 1    | 2    |      |      |      |      | 12        |
| Medical information                  |      |      |      |      |      |      |      |      |      |      | 2    |      |      |      |      |      |      |      |      | 12        |
| Privacy                              |      |      |      |      |      |      |      |      | 1    |      | 1    |      |      |      |      |      |      |      |      | 11        |
| Information processing               |      |      |      |      |      |      |      |      |      |      |      | 1    |      |      |      |      |      |      |      | 11        |
| Technology                           |      |      |      |      |      |      |      |      | 1    |      | 1    |      |      |      |      |      |      |      |      | 10        |
| Information technology               |      |      |      |      |      |      |      |      |      |      |      |      | 1    |      |      |      |      |      |      | 10        |
| Workflow                             | 1    |      |      |      |      |      |      |      |      |      |      |      | 4    | 1    | 2    |      |      |      |      | 9         |
| Patient safety                       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 9         |
| Health care delivery                 |      | 1    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 9         |
| Data mining                          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 9         |
| Smartphone                           |      |      | 2    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 9         |
| Knowledge                            |      |      |      |      |      |      |      |      | 2    |      | 1    |      |      |      |      |      |      |      |      | 8         |
| Health information systems           |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 8         |
| Content analysis                     |      | 2    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 8         |
| Systems integration                  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 7         |
| Software                             |      |      |      |      |      |      |      |      | 1    |      |      |      |      |      |      |      |      |      |      | 7         |
| Mobile application                   |      |      |      |      |      |      |      |      |      |      |      |      | 2    |      |      |      |      |      |      | 7         |
| Medical record linkage               | 1    |      |      |      |      |      |      | 1    |      |      |      |      |      |      |      |      |      |      |      | 7         |
| Machine learning                     |      |      |      |      |      |      |      |      | 1    |      |      |      |      |      |      |      |      |      |      | 7         |
| Information systems                  |      |      |      |      |      |      |      | 1    |      |      |      |      |      |      |      |      |      |      |      | 1         |
| Grand total                          | 1    | 1    | 1    | 5    | 0    | 8    | 2    | 6    | 21   | 19   | 16   | 41   | 48   | 61   | 58   | 38   | 48   | 374       |

Light blue=lowest frequency, darkest blue=highest frequency.
“Digital health journal” framework-based analysis

We categorized HI publications based on the MOH’s digital health journey framework. Only 1 publication was categorized under the first level “digital health foundations” in 1995–1999. Publications in 2000–2009 were categorized as 1.7% (n=4) “digital health foundations,” 1.7% (n=4) “digitally enabled care,” 0.8% (n=2) “smart care,” and 0.4% (n=1) “care anywhere.” Publications in 2010–2019 were categorized as 27.7% (n=67) “digitally enabled care,” 24.0% (n=58) “digital health foundations,” 17.4% (n=42) “smart care,” 17.4% (n=42) “empowered care,” 6.2% (n=15) “care anywhere,” and 2.5% (n=6) “intelligent health enterprises.”

Most publications were categorized as “digitally enabled care” (29.3%, n=71) or “digital health foundations” (26.0%, n=63) (Figure 4). Few publications (2.5%, n=6) were categorized as “intelligent health enterprises.” “Digital health foundations” showed a continuous upward trend in published research (except for between 2000 and 2002) starting in 1995, with the first publication. Publications related to “digital health foundations” reached peaks (4.1%, n=10) in 2016 and 2017. Publications related to “digitally enabled care” started to appear in 2000 and reached a peak (4.5%, n=11) in 2016. Additionally, publications categorized as “smart care” started to appear in 2004 and reached a peak (4.1%, n=10) in 2017; those categorized as “care anywhere” started to appear in 2008 and reached a peak (2.5%, n=6) in 2018; and those categorized as “empowered care” started to appear in 2011 and reached a peak (4.5%, n=11) in 2016. Lastly, publications categorized as “intelligent health enterprises” appeared only in 3 years: 2012, 2016, and 2019.

DISCUSSION

We analyzed trends in HI publications by Saudi-affiliated authors over the past two decades. In 1995–1999, there was only one publication [162], which was published before the health care services review conducted by the health reform committee in 2000 [12]. This was the first HI publication with a special focus on hospital information systems. This publication was categorized under the first level of the MOH’s digital framework, indicating the emergence of the HI field in Saudi Arabia as early as 1995.

Figure 4 Trends in publications categorized based on the Ministry of Health’s (MOH’s) “digital health journey” framework over time
In 2000–2009, there was an increase in the number of publications. Data sources varied during this period but still were limited, with medical and consumer informatics topics being top trends. The keyword “Internet” first appeared during this period, which might be due to the increased use of the Internet in Saudi Arabia at the same time [10, 163]. King Saud bin Abdulaziz University for Health Sciences’ establishment of the Saudi Association for Health Informatics [11] and the HI master program in 2005 [12] may have contributed to the highest number of publications and the occurrence of more specialized HI keywords, such as “electronic medical record” and “telemedicine.” Other keywords emerged in one publication (e.g., “prediction” and “algorithm”) [35], which aligned with “smart care” in our framework-based analysis. This time period has been seen as the maturity period of medical informatics [164]; however, HI publications in 2000–2009 were mainly aligned with the MOH’s first two levels, which may indicate that this period was an infancy stage in Saudi Arabia.

The highest number of publications was seen in 2010–2019. We believe the rise in the number of publications starting in 2010 may have been stimulated by the MOH initiative and e-Health objectives for health transformation as part of the Saudi 2030 vision. During this time period, there was a new trend with a few publications that used social media as a data source, which also emerged in the keyword analysis. Topic-based and keyword-based analyses showed increasing trends in clinical informatics and consumer health informatics and new trends in public health informatics and clinical informatics subfields. Moreover, there were trends in patient-oriented keywords. These trends were consistent with those found in previous studies [7, 8, 164]. Furthermore, there was an emergence of data science and analytics subdomains seen in keywords, such as “machine learning” [29, 96, 124, 130, 140, 165, 166], “data mining” [36, 52, 123, 134, 140, 143, 167–169], and “big data” [170–172], which was also reported by another study during the same time period [164]. Our framework-based analysis showed a distribution of publications across all levels, providing evidence of huge progress and variation in research efforts in comparison with the two previous time periods.

Our results provide several insights into current and future HI trends in Saudi Arabia. First, we found that the use of multiple sources of data for research in Saudi Arabia, such as patient or medical and real-time data, is still limited. For example, we found that most publications in our study used questionnaires, surveys, or interviews as data sources, which might pose some limitations, including limited reliability [173] and unrepresentative samples. For a fast-evolving field concerned with data science and big data, reliance on limited data sources is not sufficient to advance the HI field, which requires utilizing a variety of informatics platforms and data [173, 174]. Therefore, we believe that there is a need to not only collect health care data, but also understand and analyze data and utilize advanced technologies to derive data-driven decisions. Limited use of data sources might be due to a lack of clear regulations for data governance, including sharing sensitive data and repositories, which might limit the secondary use of health data.

With the increasing complexity of the health care sectors and fragmentation of digital services, the digital health vision was established to address such issues [14]. Recently, the Saudi Data & Artificial Intelligence Authority was established in 2019 [173, 175], and we believe that this will largely contribute to data governance regulations in Saudi Arabia. Second, unlike trends reported in the AMIA review [9], we found only one publication on data interoperability [119] and no research trends in some subdomains, such as natural language systems. Even though “health information exchange” appeared in our keyword-based analysis, keywords on standard systems for messaging and terminologies were not found. With the absence of systems that support interoperability and health information exchange, transferring patients’ medical records between different Saudi health care organizations remains a challenge due to the varying number of governing health care bodies [176]. The national strategy highlights the importance of standardization of information and processes and data completeness, which are important components that enable health information exchange and interoperability and contribute to advancing data analytics and research [13].

Third, even though the e-Health initiative is led by the MOH, we found a low number of MOH publications. Additionally, although we expected a growth of publications over years, we observed a decrease in the number of publications after 2016, which may reflect a lack of research efforts, funding sources, data sharing, and research centers. We believe that more research investment [177] and funding programs are needed, which can offer an opportunity to accelerate and increase HI publications in Saudi Arabia. Fourth, similar to previous studies that show many biomedical publications from Riyadh [177, 178], we also found that most HI publications were from Riyadh. This might be because Riyadh is the capital city, where most funding agencies are located. Lastly, we expect increases in publications in 2020–2030 and on the topics of data exchange and interoperability, artificial intelligence, national EHR, and intelligent health enterprises.

There are some limitations in our study. Our keyword-based analysis might have some limitations due to the use of different terminology sources (MeSH, Emtree, and WOS author keywords) in which some keywords might be semantically or syntactically equivalent. Matching similar keywords requires text mining and similarity-based methods that were out of the scope of this study. As this study is a scoping review, it...
might not include all HI-related publications due to the multidisciplinary nature and broad nature of the field [164, 179]. Specifically, we acknowledge that for this study, our selection of keywords in search queries was based on major AMIA classification and did not focus on subdomains. Future studies could use a more comprehensive search strategy to include more HI keywords and subdomains. Additionally, if Saudi authors did not specify their affiliations or populations of study (e.g., Saudi students studying abroad), our search strategy would not have captured these publications. Finally, we examined the publications only quantitatively and not qualitatively. Future work could qualitatively evaluate HI publications in Saudi Arabia.

CONCLUSIONS

Based on published research, 2000–2009 may be seen as the infancy stage of the HI field in Saudi Arabia. The highest number of HI publications was during the years 2010–2019. However, the generally low number of publications may reflect a lack of research efforts, funding sources, data sharing, and research centers. Due to the intradisciplinary nature of HI, we believe that exploring research publication trends and understanding how Saudi’s initiatives and governing bodies may have an effect on research is valuable to the advancement of the discipline. This is especially true given variations in policies and regulations across countries. More HI publications that focus on data exchange and interoperability, artificial intelligence, national EHR, and intelligent health enterprises might be future directions in Saudi Arabia, in alignment with the MOH’s digital health journey framework. Finally, there is a need to increase funding opportunities, facilitate data sharing, understand and analyze health care data, and utilize advanced technologies to derive data-driven decisions.

DATA AVAILABILITY STATEMENT

Data collected by authors is available through an Open Science Framework (OSF) project page at https://osf.io/q4ev3/?view_only=7d47b0bbfcb43f19fad71bb04f44de. Raw data for publications can be downloaded directly from PubMed, Embase, and Web of Science.

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SUPPLEMENTAL FILES

- Appendix A: Keywords search queries
- Appendix B: Google form for data extraction
- Appendix C: (a) Top ten Saudi institutions affiliations for all authors, and (b) the geographical distribution of publications in Saudi’s cities based on author affiliation

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