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Altmetric, Bibliometric and Visualized Study of the top 100 Most Cited Papers in Digital Health

Dijital Sağlık Alanında En Çok Alıntılanan 100 Makalenin Altmerik, Bibliyometrik ve Görselleştirilmiş Çalışması

Naime Meric KONAR [1] **Aslı SUNER**[2]

[1] *PhD, Assoc. Prof., Faculty of Medicine, Department of Biostatistics and Medical Informatics, Bandırma Onyedi Eylül University, Bandırma, Turkey*

[2] *PhD, Assoc. Prof., Faculty of Medicine, Department of Biostatistics and Medical Informatics, Ege University, Izmir, Turkey*

Corresponding author

Aslı SUNER

asli.suner@ege.edu.tr

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ABSTRACT

Aim: *This study aims to evaluate the research movements in the Digital Health topic through the most cited 100 products.*

Materials and Method: *Top-100 list was obtained by the help of Web of Science Core Collection (www.webofknowledge.com) database. Bibliometric analysis was employed to analyze the documents in detail in the area in question. Altmetric attention score provided by altmetric analysis was utilized to demonstrate the effect of articles on social media. Multiple linear regression analyses were applied to reveal related factors of Citation Count and Altmetric Attention Score.*

Results: *The most-cited 100 papers in Digital Health topic were observed to be published between 2010 and 2020. Mean and standard deviation of the Citation Counts were 141.4±78. A poor positive association is noted between Citation Count and Altmetric Attention Score (r=0.256, p=0.012). Multiple linear regression analysis findings show that "Q2 level (p=0.050)", "AAS" (p=0.002), "Since 2013 Usage Count (p<0.001)" and "Duration after Publication (p=0.002)" are significant factors for Citation Count, while "Page Count (p=0.013)" and "5-Year-IF (p<0.001)" are factors associated with Altmetric Attention Score.*

Conclusion: *The findings provide an opportunity to investigate the most current improvements in Digital Health, and its guidance on research and development offers the exploration gaps to fill over this field.*

Keywords: *Altmetric analysis, Bibliometric analysis, Digital health, Healthcare, Informatics, Health informatics*

ÖZET

Amaç: *Dijital Sağlık, sağlık risklerini kontrol etmek ve refahı artırmak için tıpta ve diğer sağlık mesleklerinde bilgi teknolojisinin kullanılmasını ifade eder. Bu çalışma, bu konudaki araştırma trendlerini, bu alanda en çok alıntı yapılan 100 makale üzerinden değerlendirmeyi amaçlamaktadır.*

Gereç ve Yöntem: *Verilere ulaşmak için Web of Science Core Collection (www.webofknowledge.com) veri tabanından yararlanıldı. Söz konusu alandaki belgelerin nitelik ve niceliğini değerlendirmek için bibliyometrik analiz kullanıldı. Makalelerin sosyal medya üzerindeki etkisini ortaya koymak için altmetrik analizle elde edilen Altmetrik İlgi Puanı kullanıldı. Atıf Sayısı ve Altmetrik İlgi Puanı'na etki eden faktörleri ortaya çıkarmak için çoklu doğrusal regresyon analizleri uygulandı.*

Bulgular: *Dijital Sağlık Alanında en çok atıf alan 100 çalışmanın 2010 ile 2020 yılları arasında yayınlandığı gözlemlendi. İlk 100 listesindeki alıntıların ortalamasının 141.4 ± 78.0 olduğu görüldü. Bununla birlikte Atıf Sayısı ile Altmetrik İlgi Puanı arasında pozitif yönde de olsa zayıf bir korelasyon gözlendi. Regresyon analizi bulguları, Q2 düzeyinin (p=0,050), Altmetrik İlgi Puanının (p=0.002), 2013'ten Bu Yana Kullanım Sayısının (p<0.001) ve Yayın Sonrası Sürenin (p=0.002) Atıf Sayısını etkileyen önemli faktörler olduğu, Sayfa Sayısının (p=0.013) ve 5 yıllık dergi Etki Faktörünün (p<0,001) ise Altmetrik İlgi Puanı'nı etkileyen faktörler olduğu saptandı.*

Sonuç: *Elde edilen bulgular, ilgili alandaki en güncel gelişmeleri araştırmak için bir fırsat sağlamaktadır. Dahası, çalışmanın araştırma ve geliştirme konusundaki rehberliği, bu alandaki araştırma boşluklarını doldurulmasını olanaklı kılmaktadır.*

Anahtar Kelimeler*: Altmetrik analiz, Bibliyometrik analiz, Dijital sağlık, Sağlık hizmeti, Bilişim, Sağlık bilişimi*

INTRODUCTION

Digital Health (DH) is a rapidly growing area that has the potential to transform the way health-care is conveyed and supervised. It could also be defined as the combination of information technology, medicine and healthcare. Information technology in healthcare has led to improved patient outcomes, increased efficiency, and reduced costs. DH encompasses a broad range of applications, including telemedicine, telehealth, mobile health (mHealth), wearable devices, electronic health records (EHRs), electronic medical records (EMRs), as well as personalized medicine are the key components of DH.

Recent years have witnessed the exceptionally rapid and remarkable progression of digitalization. As for all fields, medicine, and health sciences have also taken advantage of this development. Numerous applications that were produced in this “digital era” have enabled improved health monitoring, supporting the ‘digital health’ concept (Hswen, Brownstein, Liu, & Hawkins, 2017; Were, Sinha, & Catalani, 2019; Charbonneau, Hightower, & Katz, 2019; Faujdar, Singh, Kaur, Sahay, & Kumar, 2019; Rohmah, Rachmawati, & Mei, 2023). DH topic produced its first publication in 1995 (Galvin et al., 1995), and since then an increasing level of attention has been paid to this field. To date, the DH concept seems to be combined with several health-related areas such as nutrition (Ueland et al., 2022), medical education (Seemann et al., 2023), body anatomy (Darcy et al., 2022) as well as clinics including asthma management (Barrett et al., 2017), promoting mammograms (Bucher, Blazek, & West, 2022), cervical cancer prevention knowledge (Hombaiah, Madhu, Gopi, & Narayana Murthy, 2022), to name a few.

In the field of quantitative science, evaluative bibliometrics is a popular method used to evaluate the impact of research articles, based on absolute citation rates. The bibliometric analysis provides a useful tool for evaluating the impact of research in DH and identifying key trends and themes. The term bibliometrics was coined by Prichard in 1969, and described as "the application of mathematical and statistical methods to books and other media" (Pritchard, 1969). This statistical method allows for the evaluation of both the scientific character and weight of publications in a given field, identification of global teamwork opportunities and various resources, detection of popular research areas, as well as highlighting research gaps that require further investigation. However, this method is prone to bias, including favoring older articles and the phenomenon of "obliteration by incorporation," in which highly influential articles may not receive frequent citations (Merton, 1968; Hirsch, 2005; Park, Blackledge, Ananth, Sauer, & Brandt, 2022).

Due to potential limitations of traditional bibliometric analysis, a new metric Altmetric Attention Score (AAS) has been introduced. Altmetrics, which measure the online attention that scientific articles receive, can complement traditional bibliometric indicators and provide insights into the broader societal impact of research.

Altmetrics, also known as alternative metrics, were introduced in 2010 as a non-traditional way to capture online interest in scientific articles and calculate an AAS as a numerical product (Priem, Taraborelli, Groth, & Neylon, 2010; Altmetric, 2023). The AAS is a weighted metric that measures research influence by tracking its engagement on public and social media platforms, including social media, blogs, and forums (Warren, Raison, & Dasgupta, 2017). An automated algorithm calculates the score, taking into account the number of posts across different platforms and the quality of the sources. As an alternative to citation-based metrics, AAS provides advantages such as the utilization of a broader range of sources, gathering much more speed compared to traditional metrics in measuring research influence.

Over the years, numerous altmetric and bibliometric studies were produced in a wide range of areas such as medical (Zhao et al., 2015; Yang et al., 2020; Konar, 2021; Konar, Karaismailoglu & Karaismailoglu, 2022; He et al., 2023), health (Zhu et al., 2021; Li et al., 2023), natural (Yáñez-Dávila, Santoyo, & Santos-Raga, 2023), and life sciences (Li, Zhang, Herjavić, Wine, & Klasinc, 2014). Several studies have analyzed the most influential papers in DH, but considering its prevailing usage in various fields, there is still a need for comprehensive and up-to-date bibliometric analyses for this topic.

In this context this study aims to fill this gap by conducting a detailed analysis of the top 100 most cited papers in DH, using both bibliometric and altmetric indicators.

MATERIAL AND METHOD

Research Type

The study was conducted as a quantitive research.

Data Collection

Web of Science Core Collection (WoS) database (www.webofknowledge.com) was utilized to save the data. Bibliometric indicators were loaded from this database, including Citation Count (CC) in all WOS databases, publication year, country of origin, and authors' affiliation. The exploration was conducted with the keyword ("digital health") in the "topic" selection option. Several WoS parameters such as Since 2013 Usage Count, Duration after Publication, 180 Day Usage Count, Page Count, Cited Reference Count, Impact Factor (IF), 5-year IF, and Publication Year are used in this current study to assess their association with AAS and CC. "Usage Count" reflects the interest level for a specific output on the WoS website. The count indicates the number of times the article has been utilized by clicking the full-length links or by saving the work for use in a bibliographic tool. In that aspect, "180 Day Usage Count" reflects the frequency of the number of times an article has been reached or saved via the WoS database in the last 180 days-period. On the other hand, "Since 2013 Usage Count" specifies the count of the number of times a paper has been accessed or saved since February 1, 2013. IF of an academic journal is a bibliometric index provided by Clarivate that displays the annual average number of citations of articles produced in the last two years in a given journal. Additionally, 5-year IF is calculated as the proportion of the number of citations in the Journal Citation Reports year by the total number of articles published in the five previous years (Clarivate Analytics, 2023). The "Q-level" of a journal comes from the word "quarter" and Q_1, Q_2, Q_3 and Q_4 imply the top (first), second, third and fourth the highest IF of journals in a specific scientific category, respectively.

Inclusion Criteria

No filter, such as time, research type, language, WoS Index etc. were implemented. Outputs were recorded, and the first 100 papers were investigated.

Data Analysis

To summarize the metrics of influential articles, mean, standard deviation (SD), median, 25th, and 75th percentile values were reported for numerical variables while frequency (n) and percentage (%) were recorded as basic descriptive statistics for categorical ones. Pearson and Spearman correlation coefficients were calculated to analyze the associations between CC, AAS, and other metrics. Two different multiple linear regression models were built to discover the factors related to CC and AAS. No filter was applied for the selection of the covariates for the models, relationships between all bibliometric indicators were sought to analyse. In this regard, Enter method was utilized for variable selection, to remark the effect of each variable on the dependent variable. Significance level was taken as a two-sided p-value ≤ 0.05. bibliometrix R package (www.bibliometrix.org) (Aria & Cuccurullo, 2017), VOSviewer software (v.1.6.16), and The R programming language v.4.2.2 (R Core Team, 2023, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria) were utilized for all the analyses.

RESULTS

A total of 550 authors were included in the list of DH, with 5.74 co-authors per article and 30% as international collaboration proportion. In addition, the annual growth rate was recorded as 32.75%, specifying the increasing trend in the number of productions over 10-year time-span. Besides, all the documents in the top-100 list are noticed to be written in English and published between 2010 and 2020. The most cited 100 papers are provided in Appendix-I (Appendix-I).

Total of CC was 14140, and mean and standard deviation were 141.400 ± 78.401. The baseline properities of the top cited researches are outlined in Table 1 (Table 1).

2017 was the median year for the products, and the median of CC and AAS are 108 and 43, respectively. Article was the most common research type, and Q1 level was the category where the majority of the papers was published (Figure 1).

Table 1. Baseline Characteristics of Most-Cited 100 Articles

Variable	Mean ± SD	Median [25th – 75th]
IF	15.624 ± 31.988	7.076 [4.750 – 12.110]
IF (5-Year)	13.649 ± 21.719	7.213 [5.085 – 12.692]
Cited Reference Count	71.320 ± 56.915	57.500 [37.250 – 82.500]
AAS	119.480 ± 201.313	43.000 [23.000 – 116.750]
CC (WoS Core)	141.400 ± 78.401	108.000 [90.250 – 158.750]
180 Day Usage Count	13.560 ± 25.929	5.500 [2.000 – 13.000]
Since 2013 Usage Count	88.500 ± 136.550	48.000 [29.250 – 97.750]
Publication Year	2016.980 ± 2.265	2017.000 [2016.000 – 2019.000]
Duration after Publication	5.020 ± 2.265	5.000 [3.000 – 6.000]
Page Count	11.100 ± 6.195	10.000 [7.000 – 15.000]

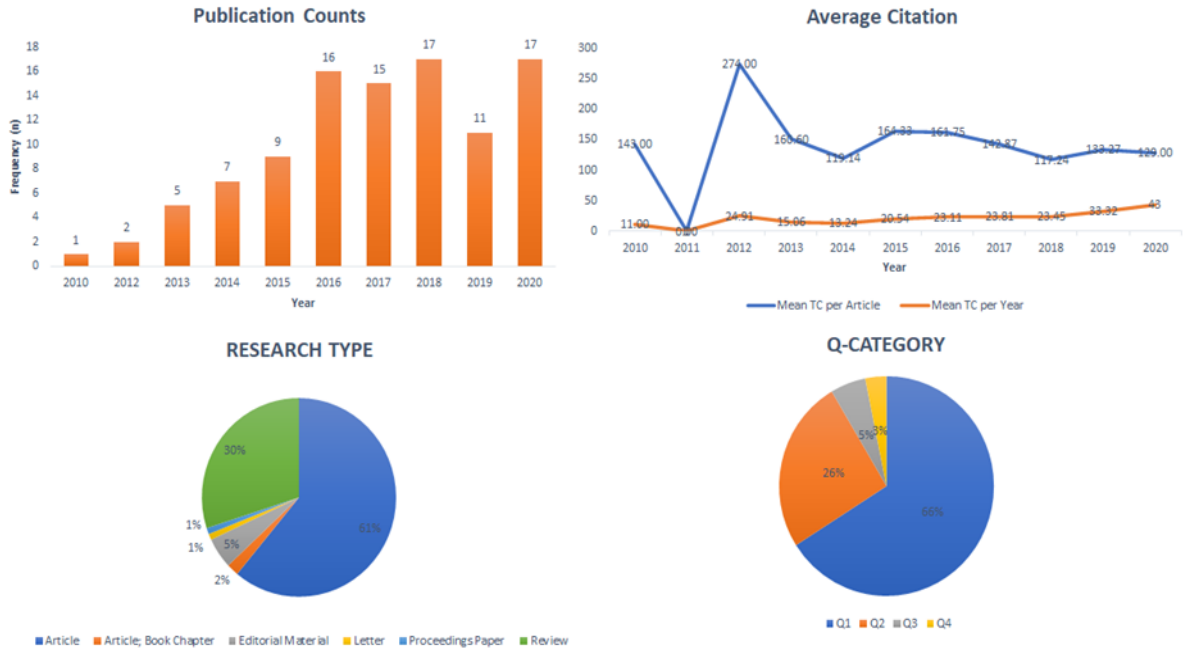

Figure 1. Several Characteristics of Most-Cited 100 Articles

The top-cited article (CC=439) is about evolving digital interventions aiming to support people resolving their health status that was produced in 2015 (Yardley, Morrison, Bradbury, & Muller, 2015). The paper that has the highest social-media influence (AAS=1114), has content of plans to enter a dissimilar group in the USA to speed up biomedical research and cultivate health and was published in NEJM in 2019 (All of Us Research Program Investigators, 2019).

There were a total of 23 countries in the list. The main contributor is the USA with n=45 articles (45.9%), the UK (n=17, 17.3%), and Australia (n=7, 7%) were placed second and third, respectively. The top 10 most productive countries and journals were summarized in Table 2 (Table 2). Further, Stanford University (n=12, 3.3%), Imperial College London (n=11, 3.02%), and the University of Indonesia (n=10, 2.74%) placed in the first three lines regarding most productive institutions.

Table 2. Most Active 10 Countries and Journals in Top-100 DH List*

Country	Articles	SCP (%)	MCP (%)
USA	45	37 (82.2)	8 (17.8)
UK	17	12 (70.6)	5 (29.4)
AUSTRALIA	7	7 (100.0)	0 (0)
CANADA	4	2 (50.0)	2 (50.0)
SINGAPORE	4	1 (25.0)	3 (75.0)
SWITZERLAND	3	2 (67.0)	1 (33.0)
GERMANY	2	0 (0)	2 (100.0)
BULGARIA	1	1 (100.0)	0 (0)
CHINA	1	1 (100.0)	0 (0)
DENMARK	1	0 (0)	1 (100.0)
Country	**CC**	**Journal**	**Frequency**
USA	6027	J MED INTERNET RES	239
UK	2523	ADV MATER	126
AUSTRALIA	931	PLOS ONE	86
CANADA	603	NEW ENGL J MED	79
SINGAPORE	589	LANCET	77
SWITZERLAND	530	JAMA-J AM MED ASSOC	75
FRANCE	394	INT J PHARMACEUT	54
ISRAEL	340	BMJ-BRIT MED J	53
BULGARIA	287	JMIR MHEALTH UHEALTH	49
GERMANY	237	BIOSENS BIOELECTRON	48

*SCP: Single country publications; MCP: Multiple country publications

Results of multiple linear regression analyses revealed that "Q2 level" (p=0.050), "AAS" (p=0.002), "Since 2013 Usage Count" (p<0.001), and "Duration after Publication" (p=0.002) are significant factors for CC; whereas "Page Count" (p=0.013) and "5-Year-IF" (p<0.001) are significant factors associated with AAS (Table 3). CC seem to increase as AAS (β=0.127; p=0.002), Since 2013 Usage Count (β= 0.363; p<0.001), Duration after Publication (β=11.464; p=0.002) increase. Further, papers published in Q2 category journals are observed to decrease CC by approximately 35 counts (β=-34.481; p=0.05) compared to Q1 level journals. On the other hand, AAS scores are increasing as IF (5-Year) (β=4.789; p<0.001) increases. However these scores are seemed to negative association with Page Count (β=-7.823; p=0.013), namely AAS decreases as Page Count increases.

Table 3. Multiple Linear Regression Analysis Results for CC and AAS

Model	β	SE(β)	p-value	95% Confidence Interval for β	
				Lower	Upper
Constant	42.526	22.522	0.065	-2.808	87.861
Q_2	-34.481	17.271	0.050	-69.246	0.284
Since 2013 Usage Count	0.363	0.085	<0.001	0.193	0.534
Duration after Publication	11.464	3.45	0.002	4.518	18.409
AAS	0.127	0.039	0.002	0.049	0.206
F=7.716; p<0.001					

Model	**β**	**SE(β)**	**p-value**	**95% Confidence Interval for β**	
				Lower	**Upper**
Constant	118.762	39.694	0.004	38.952	198.572
Page Count	-7.823	3.022	0.013	-13.900	-1.747
IF (5-Year)	4.739	0.659	<0.001	3.415	6.063
F=28.710; p<0.001					

Moreover, mathematical equations, which are obtained from multiple linear regression models, are reported below both to predict CC (Eq.1) and AAS (Eq.2) values and to summarize the associations between these aforementioned metrics:

CC = 42.526 - 34.481*(Q_2) + 0.363*(Since 2013 Usage Count) + 11.464*(Duration after Publication) + 0.127*(AAS) **(Eq.1)**

AAS = 118.762 - 7.823*(Page Count) + 4.739*(IF (5-YEAR)) **(Eq.2)**

The top cited 100 researches in DH are classified into 50 research types regarding the WoS category. The first five categories can be recorded as Health Care Sciences & Services; Medical Informatics (n=21, 42%), Medicine, General & Internal (n=6, 12%), Cardiac & Cardiovascular Systems (n=5, 10%), Psychiatry (n=4, 8%), and Sociology (n=4, 8%). Research areas distribution is almost similar, the first 5 categories are the same as the WoS category for the top-100 most cited DH papers list. The majority of the publications are observed to be the outcome of medical informatics and general & internal medicine fields' combination; namely, these two major components produce 27 outputs in total and had a 54% share in the chart.

Spearman and Pearson correlation coefficients revealed moderate and weak associations between bibliometric and altmetric data. It is noteworthy that "Duration after Publication (Year)" is observed to be positively correlated with CC (WoS Core) (r=0.217, p=0.030). Namely, as expected, this finding also supports that older articles are favored with the citation counts as time after publication increases. Moreover, AAS and IF (r=0.439; p<0.001) and IF (5-Year) (r=0.458; p<0.001) are positively correlated, meaning the social media effect is increasing as the journal's reputation increases. Furthermore, CC is increasing as usage counts since 2013 increase (r=0.445; p<0.001), which is reasonable since accessible outputs were expected to increase the CC. On the other hand, however, a poor positive association is noticed between CC and AAS (r=0.256, p=0.012).

Co-occurrence analysis, offered on authors' keywords, was depicted in Figure 2. 3 was set as the minimum frequency of cases of a keyword this criteria offered 29 keywords that created 6 clusters in the top 100 most cited DH list. The indicator in the figure specifies the most currently utilized keywords from dark blue to yellow (Figure 2).

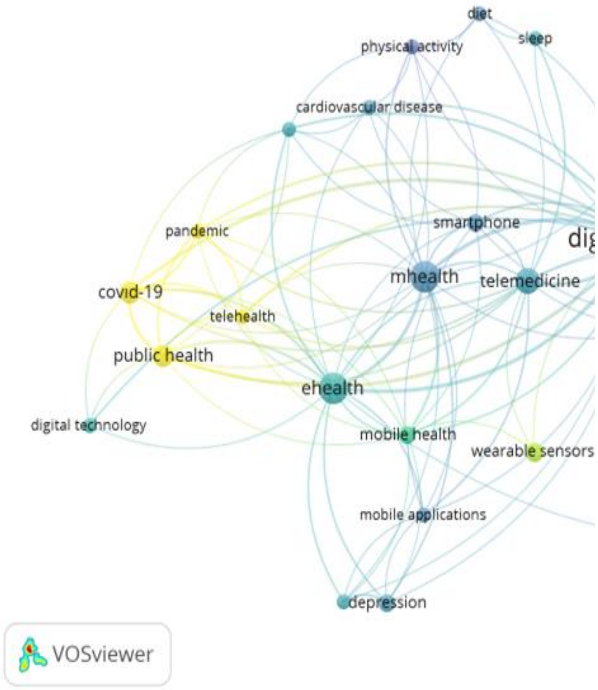

Figure 2. Co-occurrence analysis based on authors' keywords
Cluster 1: Cardiovascular disease, diet, mhealth, physical activity, prevention, sleep, smartphone, telemedicine. **Cluster 2**: Big data, healthcare, mobile apps, quantified self, self-tracking, sociology, wearable technology. **Cluster 3**: Covid-19, digital technology, pandemic, public health, telehealth. **Cluster 4**: Anxiety, depression, e-health, mobile applications. **Cluster 5**: Digital health, machine learning, sensors. **Cluster 6:** Mobile health, wearable sensors.

DISCUSSION

This study presents an all-inclusive altmetric, bibliometric study with several visualizations of the DH topic, through the most cited 100 outputs published between 2010 and 2020. Results revealed the supreme roles of the USA (in terms of both the number of productions and citation counts) and the Journal of Medical Internet Research as the major contributors to the list, and ruling positions of "article" as the research type (61%, n=61) and Q_1 level of the journals' quarter list (66%, n=66). Moreover, a weak positive association was observed between AAS and CC (WoS Core); On the other hand, several indicators such as Page Count, Duration after Publication, Q_2 level, 5-Year IF, and Since 2013 Usage Count were observed to be related to either AAS or CC metrics.

There are quite a few bibliometric and altmetric analyses in the literature that focus on health and medical informatics (Sreedharan, Mian, Robertson, & Yang, 2020; Konar, 2021; Tian & Chen, 2022; Hajesmaeel-Gohari & Bahaadinbeigy, 2022; Shaikh et al., 2023). Bibliometric analyses of DH were also conducted previously. Wamba & Querios (2021) investigated the interaction between Artificial Intelligence (AI) and DH approaches through bibliometric analysis (Wamba & Querioz, 2021). Machine learning, deep learning, and big data were reported as the most popular AI approaches as practical implications that could be used in DH projects. Yang et al analyzed the development of DH literacy over the past 20 years via a bibliometric study (Yang, Hu, & Qi, 2022). Similar to our results, the USA was listed as the lead country regarding both the number of papers and citations, the Journal of Medical Internet Research was the main contributor as a journal, and health care sciences services, and medical informatics were the main research categories regarding DH literacy. In contrast, the University of California was recorded as the most active institution in terms of DH literacy, while the DH topic itself was most productively presented via Stanford University's works, as our research results revealed. Further, they have reported Lyles, Wolf, and Schillinger as the top 3 authors, with Norman having the highest number of citations. However, the author's comparison could not be made due to the lack of this information in this work. Aagja et al provided findings regarding the evolution of digital health and mobile health based on the

publications between 1975 and 2021 (Aagja, Shome & Chandra, 2022). Similarly, the USA was described as having the most scholarly work in DH, as in this current study. A total of 6 clusters were offered in terms of co-occurrence of the authors' keywords. Co-occurrence analysis results in Yang et al's document revealed "health literacy", "internet", and "care" as the most co-occurred keywords, each one placed in a separate cluster (Yang et al., 2022). The USA, the UK, and Australia formed the top-three lines regarding the number of documents and total citations. These countries' high-level economies and welfare, which are the necessities for huge amounts of research grants as well as an adequate number of researchers in the questioned field, support the present document's findings.

Over the last years, particularly during the COVID-19 era, digital health gained great importance in both multidisciplinary and interdisciplinary areas such as patient consultation, patient monitoring, drug management, and medical education. The articles covered a range of topics in DH, but the top-cited article is related to clinical topics of expanding digital involvements to help people handle their health status whereas the top-AAS article was about biomedical research and health improvement. These two outputs are also the indicators of the widely usage of DH as well as its problem-solver property in different fields.

Bibliometrics has gained popularity due to the increasing importance of the H-score and journal impact factors in academic promotions. However, these metrics have limitations and are dependent on absolute citation rates, which can be biased. The Relative Citation Ratio (RCR) has some advantages over traditional metrics, but still relies on citation rates. Although there is a weak association between AAS and citation rates, high impact peer-reviewed journals have raised their online appearance in the previous decade, feasibly since arrangement on public programmes could lead up to the production of citations (Park et al., 2022). Compared to CC, the AAS is another option that measures research influence based on corporation with public and online platforms. However, it has limitations as it can be manipulated and does not count on citation rates. Therefore, no unique metric is adequate to specify articles of scientific interest, and a mixture of metric and analyses s may allow the most vigorous perception into research production in the medical field.

Considering there are several bibliometric analyses on DH, altmetric and bibliometric combinations regarding this topic are observed to be lacking in the literature. Hence, this work is thought to be the first and most current altmetric and bibliometric blend on DH with the comprehensive statistical analysis including correlation analysis to analyze the associations between the metrics, and multiple linear regression analysis to identify the associated factors of CC and AAS. Moreover, explanatory graphics were provided to facilitate the concept. In addition, having no time, language or index filter on the search process provided the overall framework of DH.

Several limitations of this present study could be listed as follows. Firstly, the search term, "digital health", was a general search term. Specified topics including "decision support systems", "e-health", "machine learning", "health informatics", "mobile learning", "artificial intelligence", or more certain keywords as "decision trees", or "random forest algorithm" were not utilized. Second, DH studies were only explored in the WoS database, and the outputs in other databases were not covered. Therefore, some publications in the DH area may be omitted. Moreover, self-citations were not excluded in an attempt to form a general framework of DH. Additionally, some of the outputs don't have AAS since their research type were other than article or review.

CONCLUSION

This output covers the most cited 100 papers on DH, which were published during the past 10-year period (2010 - 2020), therefore most current associations in this area were outlined via this work. This study is also thought to be the first and most current altmetric, bibliometric, and visualized research to mark and compare the findings of the outputs in DH. The results provide the insights into DH area and could be of use to investigate the most current improvements in DH and encourage the enhancement of this field via the several purposive and comprehensive applications in clinics. Moreover, it could serve as a latest guideline for international cooperation and collaboration, funding applications, and policy making. Additionally, this current work's guidance on research and development may target the exploration gaps to fill the DH area. Further, taking into consideration the fierce spread of social media effects, future research options

should include the extended and upgraded versions of altmetric studies for DH.

Author Contributions

Idea/Concept: N.M.K, A.S.; Design: N.M.K, A.S.; Supervision/Consulting: A.S.; Analysis and/or Interpretation: N.M.K., A.S.; Literature Search: N.M.K, A.S.; Writing the Article: N.M.K.; Critical Review: A.S.

Peer-review

Externally peer-reviewed

Conflict of Interest

The authors have no conflict of interest to declare.

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Appendix – I: Top 100 Most-Cited Articles in DH

Rank	Publication Title	Author(s) [Year]	Document Type	AAS*	CC*
1	The Person-Based Approach to Intervention Development: Application to Digital Health-Related Behavior Change Interventions	Yardley et al. [2015]	Article	112	439
2	Delivering Cognitive Behavior Therapy to Young Adults With Symptoms of Depression and Anxiety Using a Fully Automated Conversational Agent (Woebot): A Randomized Controlled Trial	Fitzpatrick et al. [2017]	Article	913	404
3	Global Telemedicine Implementation and Integration Within Health Systems to Fight the COVID-19 Pandemic: A Call to Action	Ohannessian et al. [2020]	Article	24	394
4	eHealth literacy: extending the digital divide to the realm of health information	Neter and Brainin [2012]	Article	39	340
5	Blockchain technology in healthcare: The revolution starts here	Mettler et al. [2016]	Proceedings Paper	-	324
6	The "All of Us" Research Program	All of Us Research Program Investigators [2019]	Article	1114	290
7	Medical Internet of Things and Big Data in Healthcare	Dimitrov [2016]	Review	266	287
8	The digitally engaged patient: Self-monitoring and self-care in the digital health era	Lupton [2013]	Article	43	277
9	Technology in Parkinson's disease: Challenges and opportunities	Espay Alberto et al. [2016]	Review	24	263
10	Adhesive RFID Sensor Patch for Monitoring of Sweat Electrolytes	Rose et al. [2014]	Article	16	258
11	Significance of Nanomaterials in Wearables: A Review on Wearable Actuators and Sensors	Jayathilaka et al. [2019]	Review	14	252
12	Annual Research Review: Digital health interventions for children and young people with mental health problems- a systematic and meta-review	Hollis et al. [2017]	Review	96	250
13	Digital technologies in the public-health response to COVID-19	Budd et al [2020].	Review	342	242
14	Digital Mental Health and COVID-19: Using Technology Today to Accelerate the Curve on Access and Quality Tomorrow	Torous et al [2020].	Editorial Material	198	228
15	Paper-Based Electrical Respiration Sensor	Güder et al. [2016]	Article	38	224
16	Evaluating Digital Health Interventions: Key Questions and Approaches	Murray et al. [2016]	Article	40	216
17	FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data	Zhang et al. [2018]	Article	12	211
18	Health 2050: The Realization of Personalized Medicine through Crowdsourcing, the Quantified Self, and the Participatory Biocitizen	Swan [2012]	Article	25	208
19	Gamification: what it is and why it matters to digital health behavior change developers	Cugelman [2013]	Editorial Material	54	207
20	Understanding factors affecting patient and public engagement and recruitment to digital health interventions: a systematic review of qualitative studies	O'Connor et al. [2016]	Article	68	200
21	Smartwatch Algorithm for Automated Detection of Atrial Fibrillation	Bumgarner et al. [2018]	Article	230	180
22	Cellphone-based devices for bioanalytical sciences	Vashist et al. [2014]	Article	4	173
23	Data for life: Wearable technology and the design of self-care	Schüll [2016]	Article	12	171
24	The 1% rule in four digital health social networks: an observational study	van Mierlo T. [2014]	Article	132	164
25	The impact of digital technology on psychological treatments and their dissemination	Fairburn and Patel [2017]	Article	33	159
26	Digital health interventions for the prevention of cardiovascular disease: a systematic review and meta-analysis	Widmer et al [2015].	Review	123	158
27	Digital Health: Tracking Physiomes and Activity Using Wearable Biosensors Reveals Useful Health-Related Information	Li X et al [2017].	Article	972	155
28	Wearables and the medical revolution	Dunn J et al [2018].	Review	63	151
29	Mobile technology and the digitization of healthcare	Bhavnani et al [2016].	Review	54	150
30	Artificial Intelligence, Machine Learning, Deep Learning, and Cognitive Computing: What Do These Terms Mean and How Will They Impact Health Care?	Bini [2018].	Article	8	148
31	Beyond the Trial: Systematic Review of Real-World Uptake and Engagement With Digital Self-Help Interventions for Depression, Low Mood, or Anxiety	Fleming T et al [2018].	Review	106	147
32	The Datafication of Health	Ruckenstein and Schüll 2017.	Article; Book Chapter	51	143
33	A progress report on electronic health records in U.S. hospitals	Jha et al	Article	16	143

		[2010].			
34	The future of digital health with federated learning	Rieke et al [2020].	Article	156	141
35	Flexible Hybrid Sensors for Health Monitoring: Materials and Mechanisms to Render Wearability	Gaoet al [2020].	Review		141
36	Energy autonomous electronic skin	García Núñez et al [2019].	Review	12	137
37	Real-world Data for Clinical Evidence Generation in Oncology	Khozin et al [2017].	Editorial Material	61	136
38	Quantified sex: a critical analysis of sexual and reproductive self-tracking using apps.	Lupton [2015].	Editorial Material	537	131
39	Universal health coverage in Indonesia: concept, progress, and challenges.	Agustina et al [2019].	Article	29	130
40	Reducing the Global Burden of Cardiovascular Disease, Part 2: Prevention and Treatment of Cardiovascular Disease	Leong et al [2017].	Review	145	129
41	mActive: A Randomized Clinical Trial of an Automated mHealth Intervention for Physical Activity Promotion	Martin et al [2015].	Review	23	129
42	3D printed medicines: A new branch of digital healthcare	Awad et al [2018].	Article	89	128
43	Prescribable mHealth apps identified from an overview of systematic reviews	Byambasuren et al [2018].	Review	8	120
44	Virtual Reality for Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration	Kyaw et al [2019].	Review	614	119
45	Adherence interventions and outcomes of tuberculosis treatment: A systematic review and meta-analysis of trials and observational studies	Alipanah et al [2018].	Review	70	117
46	Critical perspectives on digital health technologies	Lupton [2014].	Article	14	117
47	Wearable and Implantable Sensors for Biomedical Applications	Koydemir and Ozcan [2018].	Article	43	117
48	IntelliCare: An Eclectic, Skills-Based App Suite for the Treatment of Depression and Anxiety	Mohr et al [2017].	Article; Book Chapter	3	115
49	The commodification of patient opinion: the digital patient experience economy in the age of big data	Lupton [2014].	Article	362	112
50	Evaluation of smartphone-based testing to generate exploratory outcome measures in a phase 1 Parkinson's disease clinical trial	Lipsmeier et al [2018].	Article	49	109
51	Teens, Health and Technology: A National Survey	Wartella et al [2016].	Article	92	107
52	Apps as Artefacts: Towards a Critical Perspective on Mobile Health and Medical Apps	Lupton [2014].	Article	27	107
53	COVID-19-Related Web Search Behaviors and Infodemic Attitudes in Italy: Infodemiological Study	Rovetta and Bhagavathula [2020].	Article	3	107
54	Digital Health Strategies to Fight COVID-19 Worldwide: Challenges, Recommendations, and a Call for Papers	Fagherazzi et al [2020].	Article	16	106
55	Digital Health Equity and COVID-19: The Innovation Curve Cannot Reinforce the Social Gradient of Health	Crawford and Serhal [2020].	Letter	470	106
56	Aging barriers influencing mobile health usability for older adults: A literature based framework (MOLD-US)	Wildenbos et al [2018].	Article	43	103
57	Mobile Sensing and Support for People With Depression: A Pilot Trial in the Wild	Wahle et al [2016].	Article	68	103
58	First experience with a wireless system incorporating physiologic assessments and direct confirmation of digital tablet ingestions in ambulatory patients with schizophrenia or bipolar disorder	Kane et al [2013].	Review	1	102
59	Digital health: a path to validation	Mathews et al [2019].	Article	17	99
60	Computational Health Informatics in the Big Data Age: A Survey	Fang et al [2016].	Article	27	99
61	An ingestible sensor for measuring medication adherence	Hafezi H et al [2015].	Review	168	98
62	Standalone smartphone apps for mental health-a systematic review and meta-analysis	Weisel et al [2019].	Article		98
63	Wearable Sleep Technology in Clinical and Research Settings	de Zambotti et al [2019].	Article	27	98
64	A Systematic Review of Digital Interventions for Improving the Diet and Physical Activity Behaviors of Adolescents	Rose et al [2017].	Article	129	96
65	'It's like having a physician in your pocket!' A critical analysis of self-diagnosis smartphone apps	Lupton and Jutel [2015].	Review	416	96
66	IDEAS (Integrate, Design, Assess, and Share): A Framework and Toolkit of Strategies for the Development of More Effective Digital Interventions to Change Health Behavior	Mummah et al [2016].	Review	30	95
67	Effect of a Game-Based Intervention Designed to Enhance Social Incentives to Increase Physical Activity Among Families: The BE FIT Randomized Clinical Trial	Patel et al [2017].	Article	55	95
68	Long-term outcomes of a Web-based diabetes prevention program: 2-year results of a single-arm longitudinal study	Sepah et al [2015].	Article	28	94
69	The Era of Digital Health: A Review of Portable and Wearable Affinity	Tu J et al	Article	399	93

	Biosensors	[2020].			
70	Medication Adherence Apps: Review and Content Analysis	Ahmed et al [2018].	Article	198	93
71	Digital health behaviour change interventions targeting physical activity and diet in cancer survivors: a systematic review and meta-analysis	Roberts et al [2017].	Article	31	92
72	Exercise as Labour: Quantified Self and the Transformation of Exercise into Labour	Till [2014].	Review	6	92
73	A Survey of Healthcare Internet of Things (HIoT): A Clinical Perspective	Habibzadeh et al [2019].	Review	92	92
74	Unencapsulated Air-stable Organic Field Effect Transistor by All Solution Processes for Low Power Vapor Sensing	Feng et al [2016].	Review	62	92
75	Feasibility of an ingestible sensor-based system for monitoring adherence to tuberculosis therapy	Belknap et al [2013].	Article	9	91
76	Digital Approaches to Remote Pediatric Health Care Delivery During the COVID-19 Pandemic: Existing Evidence and a Call for Further Research	Badawy and Radovic [2020].	Article	3	90
77	Methods of usability testing in the development of eHealth applications: A scoping review	Maramba et al [2019].	Article	43	89
78	Has the Digital Health Divide Widened? Trends of Health-Related Internet Use Among Older Adults From 2003 to 2011	Hong and Cho [2017].	Article	13	87
79	Temporomandibular pain and jaw dysfunction at different ages covering the lifespan--A population based study	Lövgren et al [2016].	Article	88	87
80	Wearable Electrochemical Sensors for the Monitoring and Screening of Drugs	Teymourian et al [2020].	Review	7	87
81	ESC e-Cardiology Working Group Position Paper: Overcoming challenges in digital health implementation in cardiovascular medicine	Frederix et al [2019].	Article		86
82	Improvements in Stress, Affect, and Irritability Following Brief Use of a Mindfulness-based Smartphone App: A Randomized Controlled Trial	Economides et al [2018].	Review	37	85
83	3D printing: Principles and pharmaceutical applications of selective laser sintering	Awad et al [2020].	Article	117	85
84	Digital health and the biopolitics of the Quantified Self	Ajana [2017].	Article	426	84
85	How behavioral science can advance digital health	Pagoto and Bennett [2013].	Article	7	81
86	Virtual Patient Simulations in Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration	Kononowicz et al [2019].	Article	26	81
87	Using Digital Health Technology to Better Generate Evidence and Deliver Evidence-Based Care	Sharma et al [2018].	Article	54	81
88	Beyond validation: getting health apps into clinical practice	Gordon et al [2020].	Editorial Material	23	80
89	Using social media for health research: Methodological and ethical considerations for recruitment and intervention delivery	Arigo et al [2018].	Review	33	79
90	Dropout rates in clinical trials of smartphone apps for depressive symptoms: A systematic review and meta-analysis	Torous et al [2020].	Review	24	78
91	Tamper-Resistant Mobile Health Using Blockchain Technology	Ichikawa et al [2017].	Review	116	77
92	Data-Driven Cervical Cancer Prediction Model with Outlier Detection and Over-Sampling Methods	Ijaz et al [2020].	Article	60	77
93	mHealth Technology Use and Implications in Historically Underserved and Minority Populations in the United States: Systematic Literature Review	Anderson-Lewis et al [2018].	Review	160	76
94	Daily longitudinal self-monitoring of mood variability in bipolar disorder and borderline personality disorder	Tsanas et al [2016].	Article	163	76
95	Digital Response During the COVID-19 Pandemic in Saudi Arabia	Hassounah et al [2020].	Article	1	74
96	Actissist: Proof-of-Concept Trial of a Theory-Driven Digital Intervention for Psychosis	Bucci et al [2018].	Article	20	73
97	“Maternal Devices”, Social Media and the Self-Management of Pregnancy, Mothering and Child Health	Johnson [2014].	Review	40	73
98	Needed Innovation in Digital Health and Smartphone Applications for Mental Health: Transparency and Trust	Torous and Roberts [2017].	Article	34	72
99	Trends in Seniors' Use of Digital Health Technology in the United States, 2011-2014	Levine et al [2016].	Article	29	72
100	Patient engagement and the design of digital health	Birnbaum F et al [2015]	Article	75	72

*AAS: Altmetric Attention Score; CC: Citation Count.