Title
Reflection of Digital Health Technologies in Epidemiology Journals over the Past Decade: A Bibliographic Analysis

Short title
Digital Health Technologies in Epidemiology

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Take home messages

• The reflection of different digital health technologies – mobile health, health information technology, wearable devices, telehealth, and personalized medicine – in epidemiology journals increased dramatically over the past decade.

• *Pharmacoepidemiol Drug Saf* was the leading major epidemiology journal in this endeavor, publishing around one-third of all articles over the past decade which utilized digital health technologies in their methodologies.

• Overall interest in referring to the articles which have used digital health technologies increased over time.

• For improving the share of epidemiology journals in publishing literature around digital health technologies, more regular bibliographic and bibliometric analyses would be needed.

Word Count
1,503
Abstract

**Background:** Digital health – mobile health, health information technology, wearable devices, telehealth, and personalized medicine – is an advancing phenomenon in the healthcare systems of modern societies. Epidemiology has provided frameworks to support studies which utilize, evaluate, focus on, or benefit from digital health technologies in their methodology.

**Objective:** Our study systematically evaluates the articles published by major epidemiology journals, with focus on or utilization of digital health technologies, to quantify their trends and visibility.

**Methods:** All 27 PubMed-indexed, epidemiology journals were searched between 2006 and 2016, to find articles in English, in which the authors focused on, utilized, or discussed at least one digital health technology in the design, methodology, or conduct of their study. Additionally, a bibliometric analysis was conducted using the freely-available, Profiles Research Networking Software by the Harvard Clinical and Translational Science Center.

**Results:** Out of 58,251 articles published on or using digital health technologies, 368 articles (0.63%) were published by 24 epidemiology journals (307 articles [0.53%] in the past decade), with ten-year average citation per article of 3.44. More than two-third (210 articles; 68.4%) were published by five major epidemiology journals, mainly by *Pharmacoepidemiol Drug Saf*, with 98 published articles (31.9%).

**Conclusions:** The reflection of different digital health technologies in epidemiology journals increased dramatically over the past decade and *Pharmacoepidemiol Drug Saf* was the leading major epidemiology journal in this endeavor. For improving the share of epidemiology journals in publishing literature around digital health technologies, more regular bibliographic and bibliometric analyses would be needed.
**Manuscript**

**Introduction**
Digital health has become an advancing phenomenon in the healthcare systems of modern societies [1]. The U.S. Food and Drug Administration defines ‘digital health’ as “a broad scope which includes mobile health (mHealth), health information technology, wearable devices, telehealth and telemedicine, and personalized medicine.” [2]

Globally, many academics and researchers are increasingly being involved in utilizing, evaluating, and taking advantage of the benefits of various digital health technologies for their studies on individuals, populations, and/or health organizations. This increasing involvement has reflected itself in the published peer-reviewed literature on digital health, mainly as the growing number and diversity of research projects, study protocols, publications, and dedicated journals in digital health domain [3]. Also, the empowerment of healthcare system clients (including patients) and the progressive desire for innovation by industries and enterprises [4] continue to reinforce the need for valid and trustworthy scientific evidence on digital health for the benefit of public health.

Epidemiology, as the cornerstone of public health and evidence-based practice, has provided frameworks to support studies which utilize digital health technologies or focus on them. Supported by epidemiologists' inputs, the following three interconnected domains are considered valuable in those frameworks for expanding the role of digital health in epidemiologic studies: populations, study design, and follow-up; measurement; and comparison of populations and inference [5].

Over the past decade, various digital health technologies have been used continuously to strengthen and streamline the methodology and conduct of different studies. However, the actual reflection of the utilization of individual or collective digital health technologies in publications by major epidemiology journals remains to be quantified. This study aims to conduct a systematic bibliographic evaluation of the articles published by major epidemiology journals, with focus on or utilization of digital health technologies, to quantify the trends and visibility of their publications. This will help in identifying, and ultimately increasing, the share and contribution of epidemiology journals in publishing articles in which digital health technologies have been utilized.

**Methods**

*Literature search*
We systematically searched all 27 PubMed-indexed, general and specialized epidemiology journals to find articles, published in English language, in which the authors focused on, utilized, or discussed at least one digital health technology or its subtypes in the design, methodology, or conduct of their study. The time frame of search was between January 2006 and December 2016. We decided not to include the articles published in 2017, as the information on their visibility (explained below, based on citation metrics) deemed incomplete and therefore, less-conclusive.
We searched, in the articles’ metadata, for keywords recognized by the Medical Subject Heading (MeSH) classification system plus our own set of keywords relevant to digital health and associated technologies, including mobile health, electronic health, and telemedicine, expanded to include telehealth and related concepts. Details of the search strategy are provided in Appendix 1.

**Bibliographic and bibliometric analyses**

EndNote X8 (Thompson Reuters) was used for bibliographic management and analysis of references. We extracted the total number of publications from individual epidemiology journal in total and in each year, to calculate the share of publications on digital health, both over time, and by each individual journal.

To quantify the visibility of, and attraction to the published articles, we conducted a bibliometric analysis using one of the free, publicly-available, web-based solutions, i.e. the Profiles Research Networking (PRN) Software by the Harvard Clinical and Translational Science Center. Details of the methodology behind this specific solution and the range of metrics the PRN Software provides is explained on its dedicated website (2). In summary, we extracted the PubMed IDs of all articles stored in the EndNote library and pasted them onto the PRN Software’s website to get calculations for common article metrics, including citation counts and h-index, and to report the total number of times all the articles were cited (overall visibility), and, the number of times any article was cited, not including self-citations, in individual years.

**Results**

Overall, using the combination of collective keywords about digital health and related technologies, 58,251 articles were found in PubMed, in which the authors had reported the use of any type of digital health technology in their articles.

Out of the abovementioned number, 368 articles (0.63%) were published by 24 epidemiology journals, 307 articles (0.53%) between 2006 and 2016. Collectively, these 307 articles were cited 1,057 times (3.4 times per article) over the past decade. **Table 1** summarizes the temporal trend of the number of publications, and their yearly citations, for all epidemiology journals.
Table 1 – Temporal trend of the number of publications between 2006 and 2016, and their yearly citations, in all epidemiology journals which reported utilization of digital health and related technologies.

<table>
<thead>
<tr>
<th>Publication Year</th>
<th>Number of Publications</th>
<th>Cumulative Number of Citations*</th>
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<tbody>
<tr>
<td>2006</td>
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<td>2016</td>
<td>58</td>
<td>290</td>
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<tr>
<td>Total</td>
<td>307</td>
<td>1,057**</td>
</tr>
</tbody>
</table>

* From PRN Software, the number of times any article was cited, not including self-citations, in that year.

** Based on 305 recognized PubMed IDs. Overall ten-year average citation per article is 3.44 (1,057 divided by 307).

More than two-third of the articles (210 articles; 68.4%) were published by five major epidemiology journals, namely, Pharmacoepidemiol Drug Saf [PDS] (98 articles; 31.9%), Infect Control Hosp Epidemiol (53; 17.3%), J Clin Epidemiol (22; 7.2%), Am J Epidemiol (20; 6.5%), and Epidemiology (17; 5.5%). Figure 1 visualizes the share of the top five journals over time between 2006 and 2016, by illustrating the temporal trend of the number of publications in all 24 epidemiology journals and independently in the top five journals.
Figure 1 – Temporal trend of the number of publications between 2006 and 2016 in all 24 epidemiology journals (dark blue line) and independently in the top five journals with the largest number of publications, indexed as utilizing any of the digital health technologies in their methodology.

Discussion
The reflection of different digital health technologies – mobile health (mHealth), health information technology, wearable devices, telehealth and telemedicine, and personalized medicine – in epidemiology journals increased dramatically over the past decade.

Interestingly, Pharmacoepidemiol Drug Saf was the leading major epidemiology journal in this endeavor, publishing around one-third of all articles published in epidemiology journals which utilized digital health technologies over the past decade. The next four major epidemiology journals published around another one-third of the articles.

Although the share of publication by epidemiology journals is still less than 1%, the increasing trend happened both in terms of the number of publications, and their corresponding citations, as an indicator of visibility. We did not provide the average citation per published article per year, as it could be non-informative, if not misleading [6]. The reason was that the total citation counts by PRN Software are recorded for all articles published up to the corresponding year, and therefore, shows the visibility of all articles published ‘up to’ that year, not just the ones published only ‘in’ that year. Nevertheless, the overall ten-year average citation per article of 3.44 is positioned in the middle of the yearly and five-yearly impact factors of the epidemiology journals. This finding, in addition to the dramatic increase in the cumulative number of citations over years is a helpful indicator of the overall interest in referring to the articles which have used digital health technologies.

In terms of the number of publications, the increasing temporal trend shown in Figure 1 could be divided into two consecutive time frames with growing, yet different slopes of change: between 2009 and 2012, and between 2013 and 2016. While before 2009, the
number of published articles showed a small upward trend, a hugely upward trend was noticeable between 2009 and 2012. Most of the articles in this time frame were published by *Pharmacoepidemiol Drug Saf* and *Infect Control Hosp Epidemiol*. This noticeable change could have happened because of the growing availability and universality of electronic health records for health research [7], which might have provided researchers with the opportunities to base their study methodology on the utilization of electronic health records.

However, after a short plateau between 2012 and 2013, the more recent upward trend happened with a smaller slope between 2013 and 2016. This could have happened because of the growing availability of telemedicine, and specifically, mobile health solution in recent years [8]. Another reason could be the efforts by the remaining three epidemiology journals to publish articles which had used comparable digital health technologies in their methodology.

Two-thirds of all articles were published by five major epidemiology journals which might reflect the overall willingness of their editorial boards to consider for peer review, and ultimately for publication, the manuscripts which have utilized digital health technologies. It may also reflect improvement in the methodologies of the published articles [9] which might have made them strong and robust enough to be accepted for publication in epidemiology journals.

**Limitations of our study**

Our study focused on English language-based journals in epidemiology which were indexed in PubMed, as a freely available database. Other journals indexed by different databases, specifically subscription-based bibliometric databases like Scopus, could be included in future research projects, to expand the scope of this analysis of the reflection of digital health technologies in epidemiology literature. Also, the citation metrics in our study were coming from one publicly-available free data source and were limited to a few commonly-used parameters. However, for the provision of a comprehensive bibliometric outlook on the publications, the utilization of other citation databases and metrics could be relevant and informative in future studies.

**Conclusion**

The reflection of digital health technologies in major epidemiology journals has been on the rise over the past decade. For keeping the momentum of this growth, and improving the share of epidemiology journals in publishing literature around these technologies, more regular bibliographic and bibliometric analyses would be needed. This would encourage authors to consider publishing their articles in epidemiology journals, and support journals to expand their supportive publication policies and become more inclusive of digital health technologies.
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Conflicts of Interest
The authors have no conflict of interest to disclose.
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Competing Interests
The authors have no conflict of interest to disclose.

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