The impact of open access on the medical literature: a review of current literature

Vpliv odprtega dostopa na znanstvene objave v medicini: pregled tekoče literature

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Izvleček

Izhodišča: Namen članka je podati pregled vpliva odprtega dostopa na znanstvene objave v medicini glede na tri kategorije: citiranost, vidnost in omembe v socialnih medijih.

Metode: Podatke smo pridobili z iskalno strategijo, ki je vsebovala ključne besede, kot so "open access", "citation impact", "citation advantage", "citations count", "article download", "article usage", "social media attention" in "altmetrics".

Rezultati: Z iskalno strategijo, ki smo jo uporabili v treh zbirkah podatkov, smo pridobili stosedem člankov, primernih za analizo. V sedeminšestdesetih člankih izmed teh se uporablja enostavna metodologija štetja citatov odprtodostopnih člankov in člankov iz naročniških revij, v devetnajst člankih se primerja število citatov in vpogledov, v enaindvajsetih člankih se raziskujejo omembe v socialnih medijih. Od tega je petindvajset člankov medicinskih, v katerih se obravnava vpliv vseh navedenih kategorij.

Zaključki: V sedeminšestdesetih člankih izmed teh se uporablja enostavna metodologija štetja citatov odprtodostopnih člankov in člankov iz naročniških revij, v devetnajst člankih se primerja število citatov in vpogledov, v enaindvajsetih člankih se raziskujejo omembe v socialnih medijih. Od tega je petindvajset člankov medicinskih, v katerih se obravnava vpliv vseh navedenih kategorij.

Abstract

Background: The aim of the article is to conduct an overview of the impact of OA on the medical articles based on 3-part categorization.

Methods: Data were identified by a search strategy with eight combinations of keywords (open access, citation impact, citation advantage, citation count, article download, article usage, social media attention, altmetrics) and searched in three different databases.

Results: The analysis was conducted on 107 studies dealing with citations, downloads and social impact. Sixty-seven of them simply employed the counting citations to OA and non-OA articles; nineteen articles compared the downloads and citations counts; and twenty-one articles investigated the social impact of OA articles. Twenty-five articles investigated the citations, download counts, and social impact of medical articles.

Conclusions: The studies investigating the citation impact mostly showed citation advantages. Those that employed citation and download counts of medical articles using randomized controlled trials showed that OA articles were downloaded significantly more frequently, but found no evidence of a citation advantage for open access articles. The citation advantage from open access maight be caused by other factors. Results of the studies comparing the social media attention and citations/ downloads of the medical articles are often diametrically opposed.

1. Introduction

The advent of the Internet and its endless possibilities for information processing and distribution has enabled an open access (OA) to scientific literature. OA has been feasible since the World Wide Web was launched, but the term itself only gained currency in 2002, when it was first defined. With OA, instead of relying on subscriptions to subsidize publishing costs, expenses are paid by sponsorships or author-side fees, which may be covered by institutions or grant-funding organizations (1). There are numerous publishing efforts to make digital versions of hundreds of journals, often published by societies freely available online. OA journal provides an immediate OA to all of its articles on the publisher's website (2). An alternative way for researchers to disseminate their work is by self-archiving which involves the authors' placing versions of their articles that are published in a traditional, subscription journals (where only subscribers have immediate access), in freely accessible archives (i.e. on their personal and/or institutional Web page or repositories/ archives).

Over the past 20 years the effect of OA on the visibility or impact of scientific publications has become one of the most important issues in the fields of bibliometrics and information science. There has been much discussion and analysis as to whether open access affects the number of times a publication is cited. Increased citation rates translate into increased impact, which is important for OA as a publishing model and for the researchers, research funders and universities. However, there is a strong correlation between the impact of OA and citations.

The intensity of impact also differs from discipline to discipline. In life sciences it is not uncommon for a researcher to produce several journal articles; but social scientists and humanities scholars concentrate on publishing monographs. This so-called disciplinary culture has an impact on publishing processes and the ways by which researchers in each discipline communicate their findings (3). The current paper explores the effect of OA on the field of medicine. A review of the literature was conducted to map the ways in which impact has been defined, measured and studied, and to identify areas for future research.

1.1 Scope and purpose of present paper

Research into the impact of Open Access uses two different methods to examine researchers' opinion on the subject and the application of metrics to measure the impact of OA: surveys and interviews. This review of the literature focuses on data from studies using bibliometric methods. The paper is primarily focused on medical articles.

The purpose of this review is to highlight the findings about the impact of open access starting with the early research. An analysis of core articles will provide evidence of critical issues that this literature has identified and reveal trends in OA research. Most of the early studies employed a traditional bibliometric tool for measuring impact – citation analysis–which counts the number of times a given article has been cited. This measure provides a quantitative proxy to the quality of the articles, authors and journals (4).

1.2 A brief history of Open Access

One of the triggers for the development of Open Access publishing was the »serials crisis« at the end of the 20th cen-

tury. Put simply, for many years, subscription costs for publications rose much faster than inflation. The emergence of the Internet, however, made it possible for anyone to publish and share information on the web. This posed new challenges and opportunities for scientific publishing. 1991 saw the creation of the first free scientific online archive or repository for physicists, called arXiv.org. Publishing articles in arXiv, however, had no effect on journals subscriptions in physics because all it did was to encourage scientists to self-archive their pre-publication articles into an online depository.

In 2000, the National Institute of Health (NIH) released PubMed Central, a digital repository of biomedical and life sciences literature that has now grown to almost 6 million articles. The NIH, the largest funder of medical research in the world, requires that papers describing research funded by the NIH must be available to the public for free through PubMed Central within 12 months of publication. Participating publishers may archive their entire journals in PMC, and thus all the articles published in those journals would appear in PMC. The publisher may also choose to deposit other, non-NIH-funded articles. Non-NIH-funded articles can be deposited by their authors or by the journals as well. The Wellcome Trust, a charitable foundation, supports an unrestricted access to published outputs. Its open access policy demands that the recipients of its grants deposit a copy of their articles with PubMed Central (5,6).

Another initiative, BioMed Central (BMC), launched in 2000, is a United Kingdom-based, for-profit scientific publisher specialising in open access journal publication. In 2002, processing fees were introduced to cover the costs of free online access (7).

The specific features of free and unrestricted availability of scientific literature are spelled out in various public statements, including the 2002 Budapest Open Access Initiative (8), the 2003 Bethesda Statement on Open Access Publishing (9), and the 2003 Berlin Declaration on Open Access (10). At a 2005 follow-up conference, the Berlin declaration was refined to two key principles–researchers should be required to:

- deposit a copy of their work in an open access repository and
- encourage the publication of work in open access journals when available.

These two concepts have given rise to what is often called "Green OA" and "Gold OA", respectively, and the two combined are referred to as an open-access mandate (10).

In 2002, Lund University in Sweden launched another open access project »The Directory of Open Access Journals« with 300 open access journals. Today it contains more than 9,000 open access journals covering all areas of science, technology, medicine, social science and humanities (11).

One final development worth noting is the Public Library of Science (PLOS). This nonprofit, open access scientific publishing project, aimed at creating a library of open access journals and other scientific literature under an open content license, was established in 2003. In 2008 it introduced article-level metrics into its journal platform, which can help users determine the value of an article to themselves and to their scientific community (12).

1.3 Measuring impact

Since Eugene Garfield founded Science Citation Index in 1964, citation counts and citation analysis have been used in bibliometric methods to trace relationships amongst academic jour-

nal citations or extract measurable data through the statistical analysis of text and information about how the text is being used (13). The results of bibliometric analysis provide the data used to measure the impact of information resources.

As noted earlier, the Internet has fundamentally changed the way in which information is distributed and accessed. The web has enabled a new system for communicating research and given rise to the Open Access (OA) movement.

The OA movement with its emphasis on sharing information freely and electronically, together with advances in digital publishing, are creating more opportunities than ever for researchers to have an impact. In this new environment, many researchers and journal publishers have begun to seek alternative impact indicators for OA resources such as mentions, acknowledgments, endorsements, downloads, recommendations, blog posts, and tweets (14).

Bibliometrics is now a fast-growing, multidisciplinary field that ranges from webometrics to scientometrics to altmetrics. The term altmetrics was coined by Jason Priem in 2010 as a broad, rapid and transient impact of scientific publishing. Altmetrics seek to measure impact not solely in terms of the number of times a scientific article gets cited but also by monitoring, tracking and measuring other aspects of scientific literature, such as article downloads, views, comments and tweets. Altmetrics provide a new way of detecting the use of scientific publishing beyond formal citation (4,15).

1.4 Early research into Open Access

The purpose of scientific literature is to disseminate research findings and provide a permanent archive. Researchers and academics are not paid for publishing. Why do they write in the absence of financial incentives? There are various reasons such as career advancement and a desire to share knowledge and advance their discipline.

As a starting point the early studies looked at the prerequisites and barriers for OA publishing. The three channels investigated were open access journals, subject repositories and institutional repositories (16). OA is not just about ensuring the dissemination of information; it is also about increasing the impact of articles made available through OA. Research into OA impact seeks to demonstrate how much an article is used and how much it is valued. The techniques for analysing scientific literature have a long history. Once scientific literature became available online, there were opportunities to carry out new types of research into the ways in which science advances. Traditional methods of determining the quality and impact of research activities have been supplemented by new methods of investigation. In particular, the original aim was to test whether there was an overall rise in citations for articles which were available through open access. The expectation was that OA would result in increased usage of published articles since OA allows research findings to reach an audience which hitherto lacked access. The expectation was that there would be a boost in citations, varying in magnitude by discipline (17).

These expectations were turned into research questions. The main issue was whether OA, by increasing visibility, findability and accessibility for research articles, would increase citations to those articles.

1.5 Debates and controversies about the impact of Open Access

The current debate about the impact of OA started in 2001 with the publi-

cation of a paper by Steve Lawrence in the journal *Nature* which analysed conference proceedings in the field of computer science. The author's conclusion was that open access maximises impact, minimises redundancy and speeds scientific progress (18). The paper stimulated debate and led other researchers to consider which factors maximise impact and the effect of OA on different fields of scholarly research. By and large the debate centred on the impact of OA on citation. One question was whether early online access (before publication in a journal) boosts citation. In the early stages of research it was assumed that OA articles would generate more citations than non-OA articles. These studies were beset with methodological problems. Determining the appropriate time after publication to measure the citation rate needs to be specified. Unfortunately, in many studies, the date on which an article was published in an OA journal was not always clear. The majority of these studies were observational, meaning that they simply observed the citation performance of two sets of articles.

The selection advantage hypothesis argues that self-archiving of original research papers increases citation rates, because authors tend to make their highest quality papers available in institutional repositories. Similarly, the early access advantage hypothesis proposes that self-archiving preprint increases citation because they are available before the publication (19).

Another point of debate relates to the analysis of article downloads as a complementary method for studying the impact of OA articles in hybrid OA journals. These are subscription journals in which some of the articles are open access. This status typically requires the payment of a publication fee (20).

Many OA journal providers offer download statistics for the articles which are proxies for article readership or article usage. This raises the question as to whether higher numbers of downloads are associated with higher citation rates. As noted previously, in recent years there has been a growing interest in the use of alternative metrics (altmetrics) to assess the impact of publications. This involves using data from social media platforms such as blogs, Twitter feeds, Mendeley, LinkedIn, Facebook, and CiteULike. Social media, especially Twitter, is increasingly used as a way of demonstrating impact in biomedicine. Haustein (21) reported that 20 % articles indexed in PubMed in 2012 received at last one tweet. This finding raises the question as to whether an OA paper which scores high on altmetrics tools actually gets much higher download and citation rates compared to a paper with a low altmetrics score.

Impact assessment is one of the major drivers in scholarly communication. Metrics used as an aid to the evaluation of research might help promote open access.

1.6 Methodology

One of the challenges of carrying out a review of current literature into the impact of open access is the growing body of empirical literature published in the recent years (22). There is also the fact that this is an interdisciplinary subject attracting researchers from diverse fields publishing in many different journals. The aim of the present study was to perform a search of peer-reviewed publications and reports in the published literature. The first step was to examine the core literature to get a sense of the themes and the critical issues that this literature has highlighted.

A preliminary scan of the literature suggested that there are two emergent themes to explore:

1. bibliometrics and altmetrics methods used to measure the impact of OA;
2. conflicting interpretations of causal factors.

It was decided at the outset to focus this investigation on the literature relating to bibliometrics and altmetrics, with a particular emphasis on literature dealing with quantitative analysis of open access. This paper will summarise the literature describing the advantages and disadvantages of open access with respect to citations, downloads and altmetrics indicators. The analysis will focus on different variables employed by the studies to test the association of OA with citations, downloads and altmetrics. It will also focus on the question whether there is simply a correlation between OA publication and the number of citations or the studies establish a causal relationship.

The review deals with studies conducted between 2001 and 2016. The key words are: open access, citation impact, download, article usage and social media. The search strategy used similar words such as citation advantage, citation rate, and altmetrics.

Searches were conducted using

- Google Scholar, a widely used academic search engine, which plays a major role in finding free full-text versions of articles;
- MEDLINE (PubMed interface), a bibliographic database produced by the U.S. National Library of Medicine;
- Emerald Insight, a database of journal articles from Emerald, a cross-disciplinary publisher, which enables access to more than 300 journals from different scientific fields;
- several bibliographies, including SPARC Eureope's (23), Wagner's (24), Hitchcock's (25) and Swan's (17).

The search covered these sources, using the key words and their Boolean combinations. The basic Boolean search operator AND was used to narrow down search results and OR to broader the search more similar concepts. The primary search strategy was "open access" AND ("citation impact" OR "citation advantage" OR »article level metrics« OR "citation count" OR "article download" OR "article usage" OR "social media attention" OR "altmetrics"). As the functions of different search engines and databases varied, it was necessary to adapt the terms to suit each one. Existing bibliographies on the impact of OA were also consulted.

While conducting the literature search, we determined which articles contained relevant data. The first step was searching by the titles of the records. Then we identified the key elements in them and filtered out any peripheral materials. 186 records of the articles are identified. All articles identified in the search were screened for relevance to the key question. Relevant data from the papers selected for inclusion were extracted or copied from the publication to a database to create the set of studies used to investigate the citation impact, downloads and social media usage of OA articles.

The criteria for inclusion were:

- articles where the abstracts contained one or more of the key search terms;
- articles which were peer-reviewed and used quantitative methods, such as counting article downloads, citations or different altmetrics indicators.

Exclusion criteria:

- studies that did not directly link with the impact of open access;
- review papers and bibliographies. However, these papers were checked later to find the missing articles;
- studies regarding the production, publishing, or availability of information (e.g. papers on the economics of scientific publishing);
- works based on personal beliefs and anecdotal evidence;
- studies of online newspapers, magazines, and trade publications;
- opinion pieces.

Once the process of identifying the key articles had been completed, a review of the literature was undertaken. Themes related to the measurement of OA impact were put into three groups:

- citation impact;
- download analyses;
- social impact of open access articles.

2 The literature review – Summary of findings

Considering that these inclusion and exclusion criteria may be modified to better identify relevant studies on a topic of open access advantages, the literature review of the scholarly literature by summarizing and analyzing published work on that topic yielded 107 research peer-reviewed articles which were divided into 3 categories:

- studies which examined citation performance of OA (no = 67);
- studies of downloads of the OA articles (no = 19);
- studies which explored the social impact of OA articles (no = 21)

Table 1: The impact of the OA articles

Citation performance of OA	No. of the articles	Percent
Impact of medical articles	5	4,67
Impact of OA and non-OA journals	11	10,28
Citation rates before and after journal articles are made openly available	6	5,61
Impact factor between OA and non-OA journals	11	10,28
Number of OA and non-OA articles	34	31,78
Σ	**67**	**62,62 %**
Downloads of the OA articles		
Downloads of the medical articles	10	9,35
Others	9	8,40
Σ	**19**	**17,75 %**
Social impact of OA articles		
Social impact of the medical articles	11	10,28
Others	10	9,35
Σ	**21**	**19,63 %**

2.1 Studies on the investigations of the citation performance of OA articles (n = 67)

The goal was to test whether there is an overall rise in citations for OA which derived from a set of assumptions:

- some of the researchers don't have access to the subscription journals that are relevant to their work;
- OA would raise the level of readership and provide a citation boost (17).

Some studies aiming to test if there is an overall rise of citations of OA articles employed the analyses between access status and citations based on:

- the investigation the impact of OA and non-OA journals (26-36);
- the comparison of the citation rates before and after journal articles are made openly available (34,37-41);
- the comparison of the journal's impact factor between OA and subscription journals (16,34,42-50).

Currently, our studies on citation counts employ three approaches:

- comparing the impact of OA and non-OA articles in the same journals;
- cross-disciplinary comparison of OA and non-OA articles;
- investigating the relationship between self-archiving and citations.

2.1.1 The citation counts of OA and non-OA articles

The methodology used by these studies in this literature review is based on the basic metric of the average citation count for the OA and non-OA articles.

In our study we included 38 articles employing the counting citations of OA and non-OA articles. We analysed the articles in regard to the comparison of the main number of citations between

- articles published OA (made freely available on the Internet) and non-OA in the same journals (green OA) and
- OA and non-OA articles been made in the repository (gold OA)

2.1.1.1 Articles published OA and non-OA in the same journals (Green OA)(n = 10)

Ten articles (written between 2004 and 2015) showed the comparison of the OA articles to articles published in the same journals that had not been made OA. Studies focused on the different disciplines as are natural sciences (agriculture, physics, civil engineering, life sciences), formal sciences (mathematics) and social sciences (anthropology, economics, law, library and information sciences, political sciences).

Most studies on the open access citation advantage (OACA) were made in the field of social sciences represented by law, economics, library and information sciences, political sciences and anthropology. The samples were very different and varied from 286 records in three international civil engineering journals (51) to 6,024 journal articles from law (52). In these studies the citations were gathered from different services as are Thomson Reuter's Web of Science (33,53-55), RePEc (53), Google Scholar (51,53,56,57), Elsevier's Scopus (51,57) or Shepard's Citation Services from LexisNexis (22,52).

The investigation on the annual comparison of OA and non-OA articles in the field of law employed the study of 566 articles (124 OA and 442 non-OA articles) from 3 hybrid journals which are published at the University of Georgia School of Law and appeared to account for almost half of the output of two law faculties (22). The study which employed

6,042 articles (3,489 OA and 2,553 non-OA) in 30 journals, each published at another faculty, included only lead articles (52). The comparison of the OA and non-OA articles on economics were made with 639 articles (508 OA articles and 131 non-OA articles) in 13 journals including different quality levels of journals (53).

The comparison between OA articles and non–OA articles in the field of library and information sciences was made by the investigation of the citation rate of 875 articles (486 OA articles, 389 non-OA articles) from 20 high-impact journals that appeared in the Journal Citation Reports (JCR) and Ulrich's Periodicals Directory lists, both with high journal impact factors (54).

Political sciences were examined in 727 articles (404 OA articles and 323 non-OA articles) from 8 top journals by impact factor (56). The data set includes journals allowing authors to self-archive any version of articles. Anthropology was represented by 667 articles (200 OA and 467 non-OA articles) from a list of ten top-ranked journals versus 10 bottom-ranked journals (58). Natural sciences represented by the studies employed the field of biology and civil engineering. Biology was represented by the studies of the articles published in the Proceedings of the National Academy of Sciences (PNAS) journal. Citation data was extracted from the Web of Science. One of the studies (59,60) used a sample of 4,388 articles (723 OA articles and 3.665 non-OA articles) published in the area of biological sciences representing approximately 90 % of the papers published in PNAS. The other study used a sample of 1,704 articles (212 OA articles and 1280 non-OA articles)(55). Civil engineering involved two studies. One of them includes 2.026 records (442 OA and 1,584 non-OA articles) in 14 journals (57) and the other 286 records (81 OA and 205 non-OA articles) (51) from 3 journals with impact factor. In both studies, the journals are categorized in the same subject category "engineering, civil" and have published the researchers from the University of Ljubljana, Faculty of Civil and Geodetic Engineering. The citation data were obtained from Scopus, Google Scholar and Web of Science (51,57).

Results

All (10) studies which used different sample sizes show the positive OACA, but reported different ranges of citation advantages. Two studies show general OACA. The research done on economics journals of different quality levels (53) showed that OA articles have on average a 307,9 % higher citation count than non-OA articles. Research on the OACA on the political sciences from 8 top journals by impact factor showed from 23 % to 74 % higher citation rates of OA articles (53). The comparison of OACA in the field of law (22,52) shows that OA articles received on average from 49 % to 58 % more citations than non-OA articles. Citation advantage was lower for OA articles in the highest-ranked journals because their contents routinely saturate their topical areas regardless of the access option by which they are available. The results of the study from library and information sciences (33) showed the OACA for articles from lower-ranked journals. Likewise, the results of the studies in civil engineering Koler-Povh (51,57) confirmed the OACA for the highest-ranked journals. Biology represented by Gaule's study (59) showed statistically insignificant OACA, while the other study showed statistically significant OACA from 10–16 months after publication (55).

2.1.1.2 Cross-disciplinary comparison of OA and non-OA articles (n = 9)

The literature in the different science disciplines reflects the activities of them. Traditionally, citation indexes provided a view within them. Some of the larger studies of OACA have taken broad subject categories rather than individual subject areas. The results of the studies regarding OACA of articles from different disciplines were compared to find out the trends.

There were nine studies that employed the cross-disciplinary comparison of OA and non-OA articles and o Ingwersen (61) compared the number of citations to 20 OA working papers and non-OA journal articles from humanistic and social science, agriculture, environmental and geo-field published in the same year by the same institute (Danish Institute for International Studies, Copenhagen) and predominately the same authors. The citation impact within 270 articles in 9 disciplines from hard (biology, economics, physics, mathematics and chemical engineering) and soft sciences (anthropology, geography, sociology and psychology) was examined by Tonta (62). The goal of the research was to find out if the OACA for hard sciences is higher than that for soft sciences. Antelman (63)examined the comparison of 1,017 articles (802 OA and 215 non-OA articles) of the 10 leading journals in four disciplines which were selected as disciplines with a tradition of active use of preprints—mathematics, electrical and electronic engineering, political science, and philosophy. Ten leading journals in each discipline were selected, as defined by Thomson Reuter's Journal Citation Reports (JCR). High-impact journals were selected as indicators of leading journals from the fields, while making no assumptions about journal quality. The articles from high impact factor journals were also chosen in two studies of Norris (30) which researched the OACA in the study of 4,633 articles in the journals of 4 disciplines (ecology, mathematics, sociology and economics). Sotudeh (64) investigated the OACA of the sample of 474,205 articles (22,549 OA articles and 475,205 non-OA articles) published in 276 hybrid journals between 2007 and 2011. The sample contained the articles from natural and health sciences, life and social sciences and humanities. Archambault (65) analysed 1 million articles in Scopus from 1996 to 2013 for 12 science fields including clinical medicine and biomedical research.

Hajjem (66) researched the citation advantages of 1,307,038 articles in 10 disciplines (biology, psychology, sociology, health, political science, economics, education, law, business, management) and used a robotic search algorithm for discovering of the OA articles and for the citations count. Xu-li (67) took sample of 12,354 original research articles (6,904 OA and 5,458 non-OA articles) which were published in 93 Oxford Open journals in 2009. They validated the hypotheses that there is OACA for OA articles, that the OACA varies between disciplines, and that there is some correlation between impact factor and OACA.

Results

Six studies pointed out the OACA (19,30,63-67) they evidenced the differences between OACA between the subject fields. Antelman (63) found an increase in citations of OA articles by 45 % in philosophy, 51 % in electrical engineering, 86 % in political science and by 91 % in mathematics. Hajjem (66) found open access produces a citation increase between 36 % (biology) and 172 % (sociology). Health science included in his research showed 57 %

OACA. Norris (19,30) included the articles from high impact factor journals, found sociology showed the greatest OA advantage (88 %) and ecology the lowest (44 %). Xia (33,58) found the OACA for 138,87 % higher over non-OA ones. He pointed out the different subjects have different OACA. OA articles from humanities journals have a negative OACA. OA with lower impact factors have stronger OACA. Sotudeh, (64) who confirmed OACA and pointed out the different OACA of different disciplines as well, explained the OACA as the authors publish their high-quality articles in OA. In his study the OACA ranged from 3,14 % in social sciences and humanities to 35,95 % in natural sciences. The OACA of the articles from 8,26 % in life sciences to 33,29 % in health sciences was 33,29 %.

Archambault (65), who produced a massive study on OACA, found an increase in OACA from 9 % in chemistry to 80 % in visual and performing art. The increase of OACA was 18 % in biomedical research and 37 % in clinical medicine.

Two studies measured the OACA indirectly. Tonta's study (62) examined whether there is a relationship between OA citation impact and the characteristics of the subject field. OA articles in physics, math and chemical engineering did not have higher research impact than the articles from economics, biology, which received twice as many citations than those in first group. He concluded that there is no relationship between the OACA and the characteristics of the subject fields (hard or soft sciences).

Only one study showed the negative OACA. Ingwersen (61), which compared OA and non-papers in the same year and by the same institute found that OA working papers were far less cited than subscribed peer-reviewed journal articles.

2.1.1.3 Citation counts of self-archived articles (n = 15)

About 15–20 % of the 2,5 million articles published annually worldwide are being self-archived by their authors today (66). Since institutional repositories at their initial stage of development in the early 2000s followed what subject-based repositories had already practiced for many years, self-archiving has become the primary way of aggregating digital collections (33). The purpose of the self-archiving of research papers is to maximize their accessibility and citation impact (68).

In our sample there are fifeteen studies dealing with the citation impact of articles which are self-archived in the different type of repositories (subject or institutional; mandated or non-mandated). Eight studies examined the OACA of articles posted in the repository arXiv (Physics, Mathematics, Computer Science, Quantitative Biology, Quantitative Finance and Statistics) compared to non-OA articles. Gentil-Beccot (31) compared citations to three sets of 286,180 OA articles: preprints (pre-peer-review) or postprints posted in arXiv and subsequently published in journals and articles posted in arXiv and never published in journals. Moed (77) compared citations to 74,521 articles articles posted to arXiv with those to articles in the same journals that were not made available through arXiv.

There are other investigations dealing with articles from a limited number of journals in order to compare the OACA of articles between subscribed articles and articles deposited in arXiv. Schwarz (69) compared 795 OA articles posted to arXiv and subscribed articles from the Astrophysical Journal. Kurtz (38,70) conducted two studies using citations from 4,271 articles in *Astrophysical journal* and 2,592 articles

in the seven core astrophysics journals. Within the sample of 4,900 articles from 16 journals, Aman (71) compared the speed until the first citation and total number of citations between articles published with an OA arXiv preprint and those without. Metcalfe (72) compared 7,000 articles from 13 major astronomy journals in order to find out if OA articles were made OA either in the arXiv or in Montana State University's solar physics Open Access archive. Henneken (73) traced the citations of the articles published in 2 astronomy and 2 physics journals. Metcalfe (74) researched 341 articles from 3 physics journals.

Three studies examined the OACA of articles posted to other subject repositories. Kim's (41) study, which employed a multi-disciplinary online repository of scholarly research called SSRN, researched citations to papers in the same journals not made freely available. The author's sample employed 4,205 articles (385 OA articles and 3,820 non-OA articles). Frandsen (75) and Mueller-Langer (76) compared the OACA of papers in the repositories from the economics. Their study involved 1,329 articles (208 OA articles and 1,121 non-OA articles) in 15 journals and gathered the pre-prints from SSRN (Social Science Research Network) and RePEc. RePEC is a collaborative effort of hundreds of volunteers to enhance the dissemination of research in economics and related sciences hat covers 1,800 archives from 87 countries. Frandsen (75) focused on the repositories in economic, namely, EconLit (published by the American Economic Association) and RePEc, and examined the impact during 10 years of open availability for about 2,000 working papers and 13,000 articles.

The other four studies examined the OACA of articles posted in institution repositories. Gargouri (68,77) examined the set of 27,197 articles in 1,984 journals posted in the institution repository from the field of engineering, biology, biomedicine, chemistry, psychology, mathematics, clinical medicine, health, physics, social sciences, earth sciences. They compared the OACA between articles with 6,215 mandated and 20,982 non-mandated status. Ottaviani (78) compared the OACA in 89,895 non-OA articles and 3,850 OA articles with embargoes posted in the University of Michigan's institutional repository. All articles in this sample were embargoed during some or all of their prime citation years. Kullman (79) examined the set of 3,470 articles (899 in full text, 2,571 with bibliographic data only) archived in the Chalmers University of Technology (Göteborg, Sweden) university repository. Snijder (80) took a sample of 400 books (300 OA books and 100 control books) in the Amsterdam University Press.

Results

Three studies out of 15 indicated no OACA. Snijder's (80) study of OACA of institution repository found no relation between OA status and citation rates. However, contrary to expectations, there was also no diminishing effect of OA status on sales. Frandsen (75) found no clear tendency towards an increase in impact of open availability. Conversely, articles in high-impact journals do show a clear tendency for citation impact to increase. Mueller-Langer's (76) study showed no OACA, but the researchers concluded there would be significantly more citations to OA than non-OA articles, if they controlled for the quality of journals, articles, institutions and preprints citations.

Twelve studies confirmed OA CA. Metcalfe (74) reported that articles post-

ed to repository gained more citations as non-OA articles. Ottaviani (78), who researched the OACA of the papers with embargos, found that citation advantages increase by 19 % when articles are made OA. The other ten studies supported an OACA, but they confirmed the early advantage and the self-selection effect (quality bias). Early advantage means the high citations achieved by OA publications may attribute to the speed with which they become available to a worldwide audience (17). Quality bias means that authors post their best articles that are more likely to be cited freely on the web. Ten studies confirm the phenomenon of early advantage (31,38,41,68-73,77,81).

Some of them found an early advantage for higher-cited articles (38,68,72,77). Gargouri (68,77) examined the difference in OACA between mandated and non-mandated articles and found no difference between them. Three studies confirmed quality bias (68,70,81). Kurtz (70) and Gargouri (65) distinguished two dimensions for quality bias found that prominent authors may more often deposit their papers in arXiv and authors— be prominent or not— may tend to deposit their better papers in arXiv. Moed (81) interpreted the quality bias as effect of more productive authors in terms of numbers of published papers.

2.1.1.4 Citation count of medical articles (n = 5)

Five studies dealt with the citations of medical articles (citation counts of OA and non-OA articles within the journals and citation counts of self-archived articles). Four studies compared the citation impact between OA and non-OA articles in the same journals, and one study investigated the citation impact of self-archived articles.

Davis's randomized controlled trial study (82) involved the sample of 11,013 articles from 11 journals. A large proportion of the articles where in the journal PNAS, which contributed nearly one-third of all articles in the dataset. Lansingh (83) compared 480 OA and 415 non-OA articles. Four subject areas were chosen to search the ophthalmology literature in the PubMed database using the terms "cataract," "diabetic retinopathy," "glaucoma," and "refractive errors." Riera (84) employed the sample of 161 articles from 1 journal from intensive care medicine. Lin (44) compared the sample of 11 OA and 13 non-OA articles from 1 hybrid journal. Research made by De Groote (85) focused on the 45,716 articles from 122 journals posted to PMC repository.

Results

Results of Lasingh's study (83) showed no OACA, but the advantage correlated with number of authors, country of publication, language, subject area and funding though not with access model. Study of Riera (84) and Davis (82) and editorial of Lin (44) showed an increase in article citations. Riera (84) found no significant difference in raw number of citations between all open access and non-open access articles, but showed a significant difference in number of citations between the most highly cited open access and non-open access articles. Davis (82) employed randomized controlled trials and reported about a small, but significant, 21 % increase in article citations. He explained that much of this citation increase can be explained by the influence of one journal, PNAS. When this journal is removed from the analysis, the citation difference reduces by 7 %. Of the 11 journals only 2 show positive and significant open access effects. De

Groote's study (85) looked at a sample of articles published between 2006 and 2009 in 122 journals, separated into categories of NIH funded or non-NIH funded and whether they were deposited in PubMed Central. An analysis of the number of times these articles were cited found that NIH-funded 2006 articles in PMC were not cited significantly more than NIH-funded non-PMC articles. The 2008 Public Access Policy which required mandatory deposit of articles is likely to a factor responsible for an increase in citations. The consequences were that 2009 NIH funded articles in PMC were cited 26 % more than 2009 NIH funded articles not in PMC, 5 years after publication.

2.2 Studies on the investigations of downloads and citations of the articles (n = 9)

A complementary method for studying the advantages of OA is an analysis of article downloads. Downloads is the proxy for articles readership and usage. Measuring downloads means measuring the abstract downloads, full text (HTML) downloads, PDF downloads, and measuring of unique visitors to an article (86). An important research question is whether there is a correlation between downloads and the number of citations of OA articles.

Nine studies compared the OA articles downloads and citations. Three studies focused on multidisciplinary sciences. Three studies examined the articles from 1 journal only. Three studies dealt with citation and download impact of self-archived articles. The samples included different size of articles.

Two randomized controlled studies focused on the comparison between OA citation and download advantage of the articles from the multidisciplinary sciences, including medicine. A Davis study (87) sample of 3,265 articles (712 articles randomly assigned OA articles and 2,553 subscription-access articles published in 36 journals) and compared article downloads and number of citations between these OA articles and subscription-only controls in the same set of journals. Another Davis study (88) used a sample of 3,245 articles of which 712 are OA published in 36 journals, comparing article downloads 12 months after publication and citations after 3 years between gold OA and non-OA/green OA articles.

Three studies that looked at articles posted to various repositories compared the citation and download advantages of articles. The studies dealt with the articles from arXiv, the subject repository of physics, mathematics, etc. and articles from RePec, the repository of the economics. Davis (86) examined 2,726 articles in 4 math journals, 511 articles were deposited in arXiv, with the remaining 2,254 were not. Asif-ul Haque (89) examined 23,165 articles from arXiv. Chu (90) studied the top 200 downloaded papers from RePEc.

Four studies employed the comparison between citation and download advantages of specific journals: *Tetrahedron Letters, Journal of vision, Decision Support System, Journalism and Mass Communication Quarterly. Tetrahedron Letters* is an organic chemistry journal available in Elsevier's ScienceDirect platform. The sample included 1,190 papers (81). *Journal of Vision* is an OA biological journal with 153 articles in the sample (91). *Decision Support System* is a journal for contributions from decision theory, economics, econometrics, statistics, etc. The sample included 994 articles available in ScienceDirect (92). The sample of Ha's study (93) employed the articles from the journal, *Journalism and Mass Communication Quarterly*, and included 99 articles.

Results

Four studies compared citation and download advantages of the OA articles from the multidisciplinary sciences and found no positive relationship between them (87,88,94,95). Davis (94) showed that articles deposited in the arXiv received significantly more citations than non-deposited articles and a fewer downloads at the publisher's website than non-deposited articles. Davis's studies from 2010 and 2011 revealed that OA articles received significantly more downloads within the first year, yet were cited no more frequently, nor earlier, than non-OA articles within 3 years. Davis explains the articles downloads and citations measure two different dimensions of scientific knowledge transfer. Downloads measure the general interest in a particular new piece of knowledge while citations measure a different set of intentions from a group of participants in order to generate new scientific knowledge (87,88,95).

Five other studies showed the positive relation between citations and downloads. Ha (93) employed the sample of 99 articles from 1 journal and reported that downloaded articles influenced the boost of short-term citations only. Studies of the papers deposited in repositories and for the papers from 1 discipline indicated a stronger connection between citations and downloads. Asif-ul Haque (89) considers the positional effects on early download and correlate a variety of downloads with long-term citations. The results of O'Leary's (92) study show that a downloaded paper receives twice as many citations. Watson (91) found out citations and downloads increased with article age in a characteristic way, but relative to downloads. Moed (81) discovered that more downloads of citing documents led to more downloads of the cited article through the citation. An analysis of 1,190 papers in the journal during a time interval of 2 years after the publication date revealed that there is about one citation for every 100 downloads.

2.3 Medical articles (n = 10)

Eleven studies compared the citations and download advantages in the field of medical sciences. Four studies are longitudinal, and retrospectively examined citation and downloads and the effect of PubMed Central on articles downloads. Their samples are very large. Randomized controlled trails were made for 13,223 articles (5,999 published into PMC, 7,224 control) from 14 biomedical research journals in nutrition, experimental biology, physiology, and radiology (96) and 3,499 articles (1,886 treatment articles, which were deposited and made freely available 12 months after publication and 1,613 articles available to subscribers) in PMC published in 12 physiology journals (97). The comparison was made between articles downloaded from the journals' site and the PubMed Central archive from 12 months through 24. Two other randomized controlled studies examined a sample of 1,619 articles from 11 physiology journals and compared downloads and citations between articles made OA immediately on publication (randomly picked) and those made OA 12 months after publication in subscription-only journals (86,95). One randomized controlled study examined a sample of 712 OA articles and 2,533 control articles that were accessible by subscription (87).

The other six studies were observational. Two studies compared the citations and downloads within oncology journals. Nieder (98) made a correlation between article download and citation from 250 most viewed articles between 5

BioMed Central (BMC) open access oncology journals. Four studies examined the articles from ScienceDirect journals. Schlögl (99) examined 4,164,432 papers from 50 oncology journals; one study examined journals from pharmacology (100); and one study looked at 1,636 articles (935 subscription and 701 OA articles) from one pediatric journal (101). Nicholas (102) investigated the *Nucleic Acids Research*, which employed author-pay publishing model.

Results

Seven articles (60 %) showed no positive relation between citations and downloads (86,87,95-98,101). Davis (86-87,95) reported OA articles received significantly more downloads and were not more likely to be cited than subscription-only articles. The studies from 2012 and 2013 found the reduction in article downloads from the journals' websites when U.S. National Institutes of Health-sponsored articles become freely available from the PubMed Central repository. There is evidence to suggest that the effect of PMC is growing over time (96,97). In generally these studies found OA articles were downloaded significantly more frequently, but found no evidence of an OACA. Davis concluded the citation advantage from open access reported widely in the literature may be an artefact of other causes. Nieder (98), whose analysis focused on highly accessed articles published in 5 arbitrarily selected open access oncology journals, concluded download is not a universal surrogate for citations. Anderson (101) found out that OA articles received 7 times more citations per article than print articles.

Three other studies (67,99-100) showed a close relation between citation and download frequencies. Schlögl (99,100) revealed a moderate correlation between full-text article requests and article citations. Most of the articles are downloaded immediately after they were put online. In many cases they reach their download maximum even before they appear in print. Xue (67) also found a positive correlation between downloads and citations frequencies, i.e., higher downloads frequencies is linked to higher citations frequencies. The peak time of citations frequencies comes relatively late, in the seventh to eighth year after being published, while the downloads frequency peaks quickly in the second year after being published.

2.4 Studies on the investigations of correlations between traditional metrics and social impact (n = 10)

For as long as research outputs have been evaluated, researchers have thought how to investigate their impact. Traditionally, citations from peer-reviewed articles and publishing in journals with high impact factors are generally accepted measures of scientific impact. The Web provides the possibility to construct innovative article-level or journal-level metrics to gauge impact and influence (103). One way to do so is by maintaining an online presence and by active involvement in social media. Social media-based metrics or altmetrics may face attempts at manipulation similar to what Google must deal with in web search ranking. Metrics based on the social media could inform broader and faster measures of impact and complementing traditional citation metrics (104). Social attention may be tracked by mentions and shares of scientific papers across traditional and social media outlets, blogs, public policy documents, post-publication peer-review forums and online reference managers.

Ten studies focused on the measuring of the social impact and public attention by social media. Five of them compared the citations and social impact from multidisciplinary fields while the others covered specific fields: biology, social science and humanity, information science, life sciences and astronomy, physics and math. The social media tools they investigated were Facebook, Twitter, Google +, Blogs, Rabbit, Mendeley.

Five authors (105-109) compared citations and altmetrics activities with downloads. The study in the field of physics employed 4,606 scientific articles submitted to the preprint database arXiv.org (105). Mathelus (106) employed 296 press-released articles from 99 Wiley-Blackwell journals and check out if the blogs increased the number of citations and downloads. Wang (107) investigated 1,761 papers published in *Nature Communications* used Twitter and Facebook. Mohamedi's study (108) from the social science and humanity employed 77,287 records and measured the social attention in Mendeley. Peters's (109) study focused on astronomy and math, employed 4,045 records and measured social attention using big altmetrics data providers such as ImpactStory, Altmetric.com, and PlumX.

Five other authors (110-114) analysed the relationship between altmetrics and citations. Alhoori (110) randomly selected 23 non-OA and hybrid OA journals from the top 100 journals from all fields. Costas (111) and Zahedi (112) investigated the altmetrics presence of publications from different science fields. Mohamedi's (108) (study from the social science and humanity employed 77,287 records and measured the social attention with Mendeley. Peters's (109) study focused on astronomy and math employed 4,045 records and measured social attention using big altmetrics data providers such as ImpactStory, Altmetric.com, and PlumX. Bar-Ilan (113) sampled 57 presenters from the library and information science from the 2010 Leiden STI Conference, checking the attention generated in LinkedIn, Mendeley, Twitter, Google Scholar. Lin (114) compared 1613 papers in *Nature* and *Science* used CiteULike and Mendeley.

Results

Four studies (105-107,110) pointed the correlations of citations, downloads and altmetrics between OA and non-OA articles. They confirmed Open Access Altmetric Advantage which means that OA articles received more altmetrics than non-OA articles. Wang (107) confirmed the OACA and download advantages. Alhoori's (110) study reported a significant correlation between citations and altmetrics for NOA and OA articles. Mathelus (106) confirmed the promotion of scholarly journal articles to journalists and bloggers of press release increased the number of citations and downloads.

Seven studies investigated the correlation between altmetrics and downloads/citations claimed positive correlations but relatively weak, thus supporting the idea that altmetrics do not reflect the same concept of impact as citations (105,108,109,111-114). Peters (109), Bar-Ilan (113) and Xuemei (114) found the Mendeley as the most powerful tool for articles sampling. Shuai (105) found that volume of Twitter mention is statistically correlated with downloads and early citations. Costas (111) showed that Twitter has a stronger focus on general medicine, psychology and social sciences as these disciplines have a higher density of tweets per publication than other disciplines.

2.5 Medical articles (n = 10)

Ten articles compared the downloads and/or citations and altmetrics scores. Seven studies investigated the relationship between altmetrics and citations. Two of them (104,115) examined the articles PLOS. Lin's (115) study of 33,128 records investigated the correlation between citations and altmetrics score, and Priem's (104) sample contained 24,331 papers that compared Mendeley mentions and citations. Two large samples included 1,4 million documents (21,116), which were covered in PubMed and Web of Science (WoS). One of them investigated the relationship between tweeting and citations (21) and the other analysed how often articles are mentioned on Twitter or saved by users on Mendeley (116). Eysenbach (103) employed a sample of 55 articles from the journal called *Journal of Medical Internet Research* in order to investigate if tweets can predict highly cited articles. Thelwall (117) examined 208,739 PubMed articles with altmetrics tools (Twitter, Facebook, Google +) and citations. Barbic's (118) sample included 200 most frequently cited articles published in emergency medicine journals, conducted a cross-sectional analysis of citation classics and altmetrics scores from emergency medicine journal.

Three studies investigated the correlation between download, citations and altmetrics with blogs, Twitter and Facebook. Allen (119) took the sample of 16 articles from the field of clinical pain sciences. Tonia (120) employed randomized controlled trials for articles published in the journal *International Journal of Public Health*. One study employed the randomized controlled trial to investigate the relationship between downloads and altmetrics only for 243 articles from journal *Circulation* (121).

Results

Studies investigated the correlation between citation and altmetrics and showed different results. The results of Liu's (115) and Thelwall's studies (117) showed that the altmetrics are related to citation counts. Priem (104) and Barbic (118) found a moderate correlation between altmetrics and citations. Eysenbach (103) found tweets can predict highly cited articles within the first 3 days of article publication. Haustein (21) found the number of Mendeley readers and tweets are two distinct social media metrics. The results of Haustein's study showed that tweeting behaviour varies between journals and specialties and correlations between tweets and citations are low (116).

The studies investigating the relationship between downloads, citations and altmetrics found the dissemination of research through social media increased the number of downloads and also found no relationship between citation count and altmetrics (119). Social media attention had a significant effect on downloads and citations (120). A study that researched the relationship between downloads and altmetrics reported that a social media strategy did not increase the downloads of the articles (121).

3 Discussions

By looking into articles about OA impact on citations, downloads and altmetrics, which were written over a period of 16 years, we can conclude that their explanations of the OA impact don't provide a definitive answer.

Early studies were observational and confirmed OACA; generally they affirm an overall OACA variable by discipline, from 23 % OACA in political discipline (56) to 307 % OACA in economics (53). Thirty-seven (29 %) of the obser-

vational studies used the method based on citation analyses, and 27 of them simply confirmed a positive correlation between open access and citation counts. Analysed articles were mostly taken from high quality journals.

There were only five studies focused on medical articles which mostly confirmed OACA, whereas some others were doubtful about it (44,82,84). Davis (82) investigated the OACA using randomized controlled trials and concluded the OACA was influenced by one journal only, which contributed nearly one-third of all articles. Riera (84) showed a significant difference in the number of citations between the most highly cited open access and non-open access articles.

The studies on the citations count were observational studies, in which the researchers did not manipulate or control independent variables, but only observed the differences. De Groote (85) investigated the OACA of deposited PMC articles employing the sample of the OA articles with Public Access Policy, which required mandatory deposit of articles. Some other studies employed the samples of OA self-archived and subscribed articles and confirmed confounding variables such as the quality bias (31,38,41,68-74,77,81). Confounding variables were a methodological problem in observational studies. The other problem is also the different size of samples. Some studies made the research with 99 articles only, but the other with more than 20,000 articles (68,77).

On the basis of evidence based medicine involving a hierarchical system of classifying evidence the experimental studies were introduced with a higher level of evidence. In the research of OACA, randomized controlled trials were selected as a type of methodology used to isolate the effect of the treatment under investigation. The results of these studies showed little evidence that open access status has an independent effect on citation counts but is significantly associated with more downloads and more unique visitors (86,87,95-98,101).

Social metrics, the new concept based on the idea that scientists and the public leave digital traces on the Internet when searching for or using information, provide the opportunity to gather novel metrics from other sources that provide data in a structured format (103). In our review there are 10 articles dealing with social impact of medical articles. Many studies employed different social media tools and measured social metrics attention with one or two tools. The investigations of social media attentions and citations/downloads showed the correlation between them.

4 Conclusions

Our review of the literature focused on quantitative studies: bibliometrics and webometrics.

We posed two questions at the beginning of this article: "Do open access articles increase the citations, downloads and social impact?" and "Is there any causal relation between them?". Most of the observational studies showed a correlation between the OA articles and higher citation counts. However, these results were interpreted as causal and implied causality without due consideration of potential confounding factors. A certain amount of methodological deficiencies means that findings about the relationship between OA and citation counts were incomplete and therefore suitable for further research. However, the group of articles using experimental analysis has not confirmed any causal relationship and has actually shown a more complex set of confounding factors such

as a quality, early access, or self-selection bias which are the contributors to the effect itself.

Due to the fact that researchers have increasingly moved online, the traditional metrics are not able to follow non-traditional web-based services such as tweets, likes, shares, bookmarks, views, downloads and mentions. These outputs have been measured by alternative metrics or altmetrics which reflect the different concept of impact. The conclusions of altmetrics researches in the field of medical articles are often diametrically opposed:

- The altmetrics are related to citation counts (115,117,119); there is a moderate correlation or a week positive correlation between them (104,118); and altmetrics and citations measure different things.
- The altmetrics are related to downloads (119-121). The dissemination of research through social media increased the number of download (119), but a social media strategy did not increase the downloads of the articles (120,121).

Altmetrics, an alternative means to assess the research impact, is still in its infancy. One of the challenges is to provide a reliable, relevant and standardized way for measuring research impact. Within medicine, the social media usage has been growing very rapidly (122). Future attention should be paid to the connections between citations activities and mentions on social media in order to better understand whether social media may increase the impact of articles or articles may cause more social media attention. In view of current researches who are not able to explain these connections through the formal network, it is recommended to use additional methods as are authors' interviews examining researchers' opinions and perceptions of the OA advantages. These methods may contribute to the understanding of the articles transmission through the informal network, i.e. outside the core research community.

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