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Scientific citations favor positive results: a systematic review and meta-analysis

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Abstract

Objectives: Citation bias concerns the selective citation of scientific articles based on their results. We brought together all available evidence on citation bias across scientific disciplines and quantified its impact.

Study Design and Setting: An extensive search strategy was applied to the Web of Science Core Collection and Medline, yielding 52 studies in total. We classified these studies on scientific discipline, selection method, and other variables. We also performed random-effects meta-analyses to pool the effect of positive vs. negative results on subsequent citations. Finally, we checked for other determinants of citation as reported in the citation bias literature.

Results: Evidence for the occurrence of citation bias was most prominent in the biomedical sciences and least in the natural sciences. Articles with statistically significant results were cited 1.6 (95% confidence interval [CI] 1.3-1.8) times more often than articles with nonsignificant results. Articles in which the authors explicitly conclude to have found support for their hypothesis were cited 2.7 (CI 2.0-3.7) times as often. Article results and journal impact factor were associated with citation more often than any other reported determinant.

Conclusion: Similar to what we already know on publication bias, also citation bias can lead to an overrepresentation of positive results and unfounded beliefs.

Keywords: Citation bias; Outcome bias; Meta-analysis; Systematic review; Questionable research practices; Research integrity

1. Introduction

Citations are key elements in the evolution of knowledge. They enable particular research findings to survive over time and to develop into academic consensus. Given the large body of scientific literature, it is often unfeasible to cite all published articles on a specific topic, and so, some selection needs to take place. If this selection is influenced by the actual results of the article, then citation bias occurs [1].

Citation bias is considered to be a questionable research practice (QRP). QRPs are suboptimal and undesirable behaviors of scientists that lie between responsible conduct of research and research misconduct or fraud (fabrication, falsification, and plagiarism) [2]. QRPs are often not deliberate, and their individual effects are assumed to be less severe than those of research misconduct.

Nevertheless, questionable research practices are believed to occur frequently and may have a strong negative impact on the development of knowledge [2]. A well-known example is publication bias, which leads to an overrepresentation of positive results in the scientific literature. According to a meta-analysis of surveys [3], researchers report to engage in QRPs (about 34%) much more often than in research misconduct (about 2%). Similarly, in a recent survey among researchers, selective citation was ranked as the most frequently occurring

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What is new?

Key findings

- Citation bias seems to exist throughout the sciences. Most evidence has been generated in the biomedical sciences, and some also in the social sciences.
- Positive articles are cited about twice as often as negative ones.

What this adds to what was known?

- This is the first systematic review and meta-analysis of citation bias.

What is the implication and what should change now?

- Relevant literature is often not well represented in scientific publications. This can lead to false beliefs and research waste.
- Journals and authors can both contribute in clarifying the rigor of their literature search. This can be achieved by including a statement on the representativeness of the cited literature, or, in case of an ad hoc reference, by explicitly stating that it is merely an example for the sake of argument.

research misbehavior [4]. To assess the potential consequences of citation bias, a proper understanding of its ubiquity is required.

Citation bias has been documented for several fields and disciplines, but to our knowledge, no systematic review exists. Our first aim was therefore to identify and assess all published evidence on citation bias, regardless of scientific discipline. Our second aim was to quantify the overall impact of article results on the likelihood of being cited.

2. Materials and methods

2.1. Search strategy

All publications reporting empirical evidence on the association between article results and citation frequency were included. To identify these publications, we developed an extensive search strategy (see Fig. S2 in the Supporting Information at www.jclinepi.com and also available at http://hdl.handle.net/10411/20710 for the exact search strategy.). Roughly, it consists of three facets:

a) ‘‘citation bias’’;
b) ‘‘publication bias’’ (with the restriction that it should be related to citation);
c) the combination of ‘‘article results’’ and ‘‘citation frequency.’’

This search strategy was applied to the Web of Science Core Collection. Because most of the studies on citation bias turned out to be conducted in the biomedical field, we extended this search strategy to Medline, as was laid down in our research protocol [5]. Both searches were performed on November 20, 2016. Reference lists of included publications were also checked. There was no restriction with regards to year of publication. The selection process was done in duplicate (B.D. and M.J.E.U.). Disputes were resolved by a third researcher (G.M.H.S.).

2.2. Data extraction

The following characteristics were extracted for each included study: first author, publication year, scientific discipline (social sciences, biomedical sciences, natural sciences, or multiple disciplines), article selection method (claim-specific, review-based, or journal-based), type of article included (trial, any primary data study, meta-analysis, or any type of article), operationalization of article results, other potential determinants of citation included in analysis, conclusion on the occurrence of citation bias (citation bias found, no citation bias, mixed results, or unclear), total number of articles (sample size), total number of citations, and total citation time. With citation time, we mean the time period over which the citations have been accumulated. Data extraction was performed in duplicate (B.D. and M.J.E.U.).

For the meta-analysis, we extracted or calculated additional information: the number of positive articles, the number of negative articles, the number of citations to positive articles, the number of citations to negative articles, the citation time of all positive articles together and the citation time of all the negative articles together. If necessary, we approached the authors of the citation bias studies at least twice to retrieve missing information.

2.3. Meta-analyses

Citation data are nonparametric. Therefore, we used rate ratios to pool these data. The rate is the total number of citations within a certain time frame. The rate ratio is the ratio of the citation rates in the positive outcome articles vs. the negative outcome articles. We used the inverse-variance method with random effects for pooling of the natural logarithms of the rate ratios. Four meta-analyses were performed, one for each of the following operationalizations of the article results:

1. Relationship between *statistical significance* of the results (regardless of their direction) and citation frequency. Articles with statistically significant results ($\alpha = 0.05$) are considered positive, and articles with

statistically nonsignificant results are considered negative.

2. Relationship between *direction* of the results (regardless of their significance) and citation frequency. Articles with results in the expected direction are considered positive, and articles with results in the opposite direction are considered negative.
3. Relationship between *hypothesis conformity* (results being significant and in the expected direction) and citation frequency. Articles with results that are statistically significant in the expected direction are considered positive, articles with nonsignificant results or with significant results in the opposite direction are considered negative.
4. Relationship between *authors' conclusion* in the individual articles (regardless of the actual data) and citation frequency. Articles in which the authors conclude to have found support for the tested hypothesis are considered positive, articles in which the authors conclude not to have found support are considered negative.

Authors were contacted multiple times to request any missing information. If we could not retrieve the necessary information, we either used more specific methods to infer it (as specified in the Supporting Information at www.jclinepi.com) or else excluded the study from the meta-analysis.

2.4. Supporting information

More information on the search strategy, details about the citation bias studies, methods to calculate the rate ratio, and results of sensitivity analyses can be found in the Supporting Information at www.jclinepi.com and in our review protocol [5]. More information on the terminology we use can be found in Fig. 1.

3. Results

Our search strategy identified 47 publications (Fig. 2). Three of these publications comprised two or more empirical studies, yielding a total of 52 separate studies on citation bias, and including the citation data of more than 13,000 articles on various topics (Fig. S1 at www.jclinepi.com and also available at http://hdl.handle.net/10411/20710). Because some articles could have been included by multiple studies, we assessed the degree of overlap and estimated that at least 11,000 of these articles were unique (Text S1, Tables S2 and S3 at www.jclinepi.com).

Most of the 52 studies found evidence for citation bias in their field: 29 showed a clear effect of outcome on citation against 11 studies that showed no effect (and 12 with mixed results). The direction of citation bias was fairly consistent: with some exceptions [6,7], most studies reported that positive articles were cited more often than negative articles (Table 1).

Most of the studies are biomedical [7–42], but some also concern the social [43–49] and natural sciences [6,50,51], or a combination of these [52]. The biomedical studies ranged from highly specific fields—such as the relationship between job strain and cardiovascular disease [16], or the treatment of chronic nonspecific lower-back pain [8]—to broader categories such as cardiovascular medicine [10]. Most of these studies provided clear evidence for citation bias. Citation bias was also identified within the psychological [44,46–49] and economic [43,45] literature,

Our review can be considered as meta-meta-research. It includes different levels of research. We discern between these levels by using the following terminology throughout our manuscript:

Level 1 - An ***article*** refers to the original published work. Each article has a specific outcome (called *article results*) and *citation frequency*.

Level 2 - A ***publication*** is a published work that studies citation bias in the network of included articles. (Publications that are not primarily about citation bias but measure both article results and citation frequency, are also included.) A publication can report multiple ***studies***.

Level 3 - Our systematic ***review*** investigates all *publications* on citation bias. (Our meta-analyses use *study* as the unit for analysis, as different studies within a publication can yield different rate ratios.)

Fig. 1. Adopted terminology and levels of research.

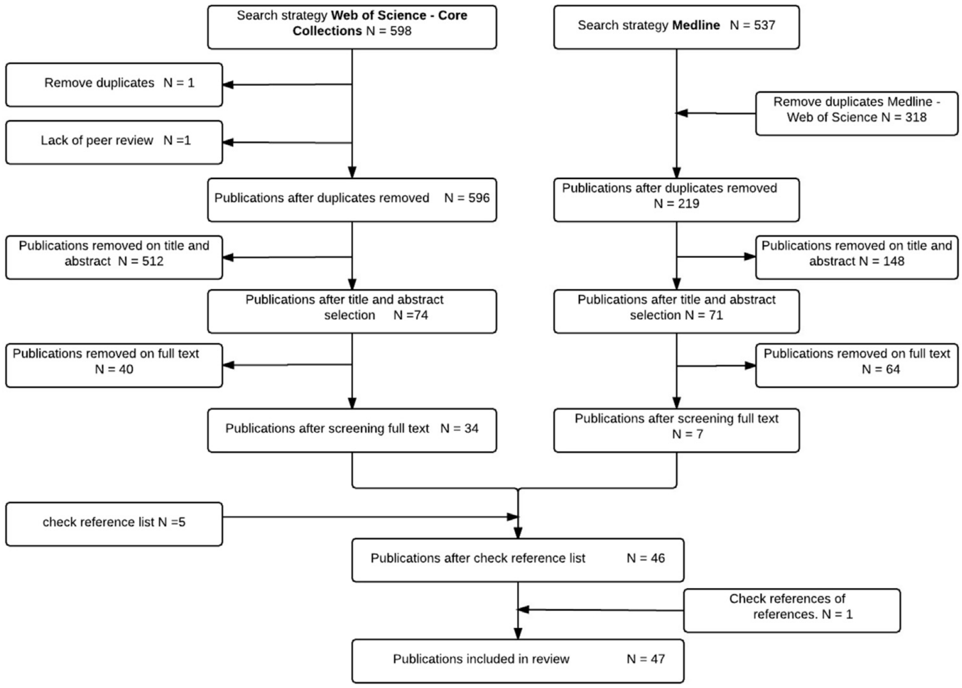

Fig. 2. Flow diagram of the article selection process.

but the evidence for citation bias in the natural sciences (mostly ecology) [6,50,51] seemed less convincing. This difference between scientific disciplines was not statistically significant ($\chi^2(4) = 5.7$, $P = 0.22$, Table 1).

Apart from scientific discipline, these studies also differ in their article selection approach. Fourteen of the 52 studies have used a claim-specific approach to study citation bias [8,12,19–25,34,40,46,47,49]. Their aim was to identify all the relevant literature studies about a specific claim and to study citation behavior within that network of articles. Another approach is to select all the articles from a specific journal or database for one or more years. Nine studies used this approach [10,17,18,26,29,31,43,45,52], whereas 20 other studies based their selection on a previously published review or reviews [6,11,15,16,25,27,30,33,35,36,38,39,41,44,48,50,51].

Claim-specific research on citation bias could be prone to selection bias as the studied claims might have been chosen according to an already existing concern of selective citation. This could potentially lead to an overestimation of the citation bias prevalence. However, this is unlikely as the journal-based selection studies showed very similar results (67% showing clear support for citation bias against 71% of the claim-specific studies). Evidence from the review-based selection studies was slightly less convincing (55% showing clear support for citation bias, and 25% showing no citation bias). This difference between

Table 1. Number of studies on citation bias, by discipline, selection method, and outcome (number of studies in meta-analyses)

Scientific discipline/article selection method	Found support for citation bias?			Total number of studies in review (meta-analysis)
	Yes	No	Mixed/unclear	
Social	6 (2)	0 (0)	1 (1)	7 (3)
Biomedical	21 (14)	8 (4)	9 (6)	38 (24)
Natural	2 (0)	3 (0)	1 (0)	6 (0)
Multiple	0 (0)	0 (0)	1 (1)	1 (1)
Claim-specific	10 (6)	2 (1)	2 (2)	14 (9)
Review-based	11 (6)	4 (2)	5 (3)	20 (11)
Journal-based	6 (3)	1 (0)	2 (1)	9 (4)
Other selection	2 (1)	4 (1)	3 (2)	9 (4)
Total[a]	29 (16)	11 (4)	12 (8)	52 (28)

Support for citation bias as stated by the authors of the included publications. Some publications present multiple studies with different results; therefore, we present the number of studies in this table.

[a] Twenty-eight of the 52 studies were eligible to be included in at least one of the meta-analyses. Inclusion in the meta-analyses does not seem to depend on support for citation bias ($\chi^2(2) = 2.2$, $P = 0.34$).

selection methods was not statistically significant ($\chi^2(4) = 1.2$, $P = 0.88$, Table 1).

3.1. Meta-analyses

Next to identifying and assessing the published evidence on citation bias, our second aim was to quantify the overall impact of the results reported in an article on how often it is cited. If available, we used data already present in the publications. For the remaining 35 publications, we contacted the authors to provide the necessary information. Despite several attempts, only 15 authors were able and willing to comply.

Twenty-one studies provided sufficient data to calculate a citation rate ratio for *statistical significance* and to pool their results in a random-effects meta-analysis (Fig. 3A). This analysis showed that statistically significant articles were cited 1.6 (95% confidence interval [CI] 1.3-1.8) times as often as nonsignificant articles. The heterogeneity was high and the rate ratio varied substantially between studies. Subgroup analyses did not reveal any differences between article selection methods or between article types

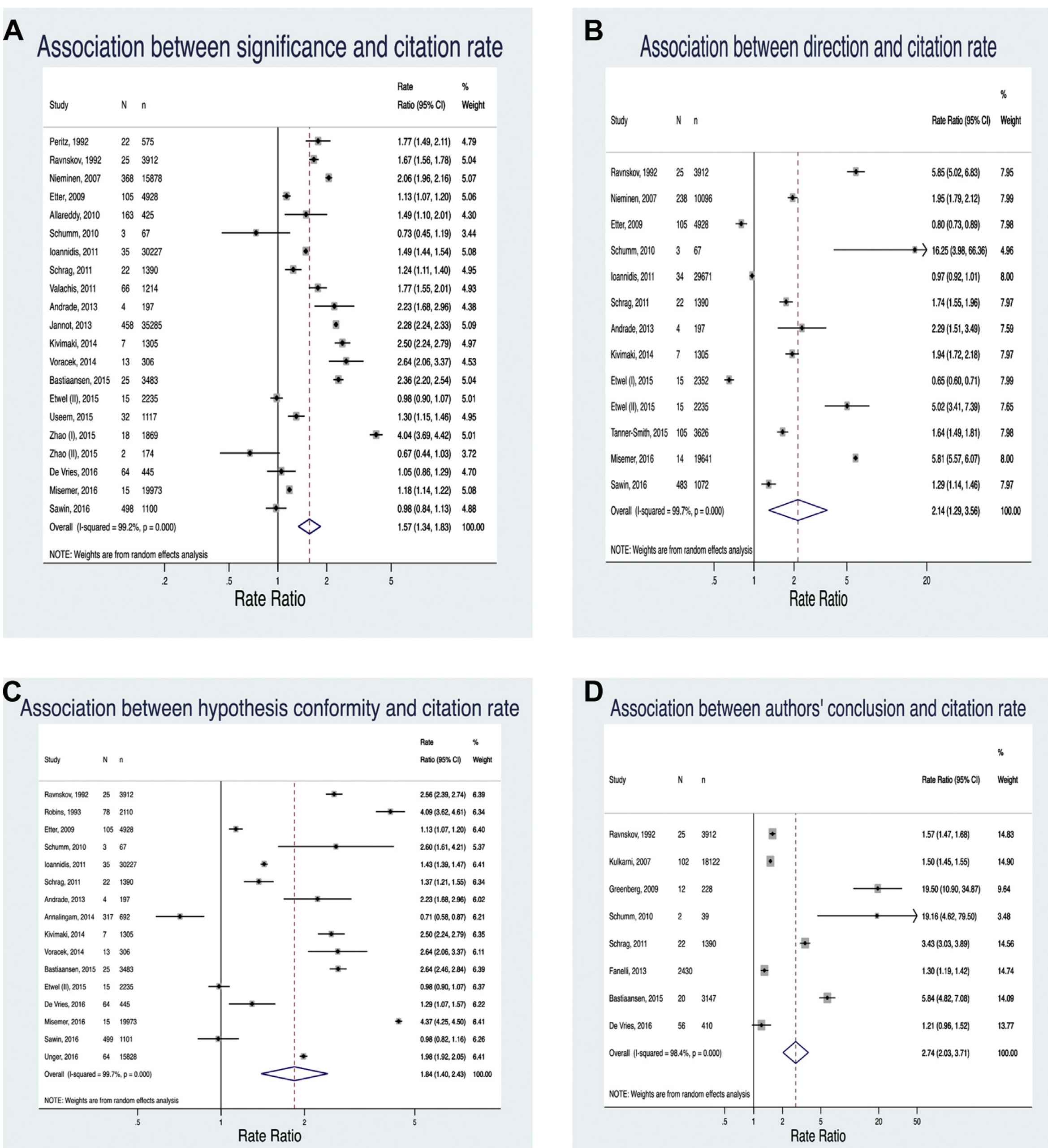

Fig. 3. Forest plots of association between article results and citation rate: (A) Statistical significance of results, (B) Direction of results, (C) Hypothesis conformity of results, (D) Authors' conclusion. CI, confidence interval; *n*, number of citations; *N*, number of articles.

(Figs. S5 and S6 at www.jclinepi.com and also available at http://hdl.handle.net/10411/20710). A sensitivity analysis, with smaller studies excluded, neither changed the pooled rate ratio nor decreased the heterogeneity (Fig. S3 at www.jclinepi.com and also available at http://hdl.handle.net/10411/20710). Although the heterogeneity was high and we could not identify its source, almost all studies pointed in the same direction: a citation rate that was higher for articles with significant results.

Statistical significance in itself is not enough to imply support for a tested hypothesis, as this would also depend on the direction of the findings. To check if some aspects of article results drive citation more than others, additional meta-analyses were performed. These analyses, one on the *direction* of results and one on *hypothesis conformity*, showed similar estimates as the one on statistical significance (with pooled ratio ratios of 2.1 [CI 1.3-3.6] and 1.8 [CI 1.4-2.4], respectively, Fig. 3B and C).

The previous operationalizations of article results are all data driven. The decision to cite an article could also be based on the authors' interpretation of the results rather than on the results themselves. There were in total eight studies on citation bias that looked at the impact of the *authors' conclusion* on citation. A meta-analysis including all these eight studies showed that original articles with a positive conclusion were cited 2.7 (CI 2.0-3.7) times more often (Fig. 3D).

All our meta-analyses demonstrated that positive articles were cited about 1.3 to 3.7 times more often than negative articles. To check whether this is representative for all published research on citation bias, we looked again at the 23 studies that were not included in any of the meta-analyses. Fifty-two percent of these studies showed evidence for citation bias (vs. 59% of the included studies), whereas 30% (14%) concluded there was no evidence for citation bias and 17% (28%) provided mixed or unclear evidence (Table 1). The difference between studies that were included in the meta-analyses and those that were not included was small and not statistically significant ($\chi^2(2) = 2.4$, $P = 0.31$). We therefore believe the double citation rates for positive studies to be representative for all published research in our systematic review.

3.2. Other determinants of citation

To evaluate which other factors determine the number of citations, we identified all potential determinants of citation as analyzed in the 47 publications of our review, and scored how often they showed an impact on citation frequency (Table 2). In these publications, article results (76%) and also journal impact factor (JIF, 89%) were more often associated with citation frequency than justifiable determinants such as research quality (17%), sample size (29%), and research design (50%). In some of the aforementioned publications, the most recent impact factors were taken for each journal. In these cases, the article of interest was published before the JIF was established, and so the determinant "JIF" could have been influenced by the dependent variable "citation frequency". Future multivariate analyses are needed to test if this result can be generalized, with JIF retrospectively measured at the moment of publication of the article.

4. Discussion

Citation bias seems to exist throughout the sciences. It is most prominent in the biomedical sciences with many studies in different fields showing evidence for citation bias. The evidence in the social sciences is also convincing, although it is based on fewer studies. The evidence in the natural sciences is more scarce and so far less convincing. Our meta-analyses show that positive articles are cited about two times more often than negative ones. Our results suggest that citations are mostly based on the conclusion that authors draw rather than the underlying data.

To our knowledge, this is the first time that all empirical literature studies on the relationship between article results and citation have been systematically investigated and that the magnitude of citation bias has been summarized in a pooled estimate. There is one earlier review, but no search strategy had been specified and only a few publications were included [1].

There is one other study that compared the occurrence of citation bias in multiple scientific disciplines [52]. This empirical study by Daniele Fanelli is also included in our review. His approach was to randomly select a number of articles published between 2000 and 2007 and score them on outcome, number of citations, and discipline. This what we call journal-based approach is powerful, but it has its caveats compared with the claim-specific approach described earlier. To give a fictional example, let us look at the health effects of fruits. Study A, on the health effects of apples, shows promising, positive results and this gives rise to a high number of additional studies on apples. Study B, on the health effects of oranges, shows negative results instead, and does not inspire more studies on oranges. It is likely that study A will be cited more often, but is this because of the positive results? Or is it because there are more follow-up studies on the same topic that are likely to cite each other? A journal-based selection approach cannot rule out this alternative explanation for citation bias, because, basically, it compares apples with oranges. In addition to Fanelli's study, our review has allowed us to check whether the occurrence of citation bias depends on the article selection approach. It turned out that this is not the case.

Most citation bias studies are performed in the biomedical sciences. This might reflect a higher awareness for this kind of biases compared with other disciplines rather than a higher prevalence. In fact, the biomedical field seems

Table 2. Determinants of citation

Determinant	Number of publications with determinant included in analysis[a]	Number of publications with determinant showing a significant effect on citation count			Percentage of publications in which determinant shows an effect on citation count[b]
		Confirms	Mixed/unclear	Rejects	
Article results	46[c]	26[d]	12	8	76%
Impact factor	19	16	1	2	89%
Sample size	19	4	5	10	29%
Research design	11	4	3	4	50%
Research topic	10	6	3	1	86%
Country of author(s)	10	5	1	4	56%
Research quality	8	1[e]	2	5	17%
Number of authors	7	4	2	1	80%
Funding source	7	4	2	1	80%
Affiliation of author(s)	3	0	1	2	0%
Authority of author(s)	2	1	0	1	50%

The classification of these determinants is based on findings from the 47 publications included in this review because it was not always possible to distinguish these determinants for each separate study (e.g., [6]).

[a] Mostly based on univariate analyses.

[b] Mixed and unclear results are ignored in the calculation of this percentage. For example, *Perc* (Article Results) = 26/(26 + 8) × 100% = 76%.

[c] One publication had measured the outcome and citation frequency of the included articles but did not analyze the relationship between them.

[d] One publication confirmed citation bias but in opposite direction, with negative articles being cited more often [7].

[e] Only one publication showed an effect of quality-related measures; it showed that lower quality was associated with a higher citation frequency [43].

generally more advanced in using initiatives to counter reporting bias and publication bias as reflected in the use of research protocols and preregistration of clinical trials (e.g., [53–55]).

The scientific process stands or falls by a balanced representation of the available research. Citation bias distorts this balanced representation and may lead to false beliefs (e.g., [56]). The good news is that there is a self-correcting mechanism in the form of systematic reviews, which ideally take all published evidence into account regardless of whether it has been cited before or not. Still, although systematic reviews and meta-analyses are often regarded as providing the best form of evidence, they can be flawed and even misleading (e.g., [57]). Furthermore, when there is no decent systematic review available, citation bias can have serious consequences that are similar to other questionable research practices (e.g., [58]).

To give some examples, studies included in our review showed that biased exclusion of previous evidence leads to distorted information in the media [44], to incorrect risk perceptions, and to unwarranted decisions such as withholding from treatment in case of a serious medical condition [33]. In addition, citation bias has led to research waste because it steered the focus of research into a wrong direction [8,12]. Furthermore, it has been shown that the conclusions of reviews (both narrative and systematic) can be predicted from the choice of which literature was cited in those reviews [59]. In other words, if this cited literature is biased, wrong conclusions can be drawn.

An underlying assumption of our approach to study citation bias is that citing articles generally agree with the cited articles. This is not necessarily the case. A positive article might also be cited to criticize the message. However, most articles seem to be cited for other reasons than critical appraisal (e.g., [60]). This propagates and reinforces the cited article's message, potentially leading to wrong beliefs if the selection of cited articles is indeed biased.

Our review has a few limitations. One limitation is the large heterogeneity of our meta-analyses. This is due to the large variety of studies included. We have performed several sensitivity analyses but could not identify the source of this heterogeneity. We therefore performed random-effects meta-analyses to take the heterogeneity into account. Nevertheless, we have to be prudent in drawing a generalized conclusion about the magnitude of citation bias across the sciences.

Further, we used rate ratios to pool effects of the included studies. The use of citation rates assumes a linear effect over time and this is unlikely to be the case. In fact, citation generally follows an inverted *U*-shape with the maximum number of citations often accumulated a couple of years after publication (e.g., [61]). In addition, the citation time over which citations have been gathered often varies between the studies that are included. But within most of these studies, the positive and negative rates are based on the exact same citation time, yielding rate *ratios* that can in principle safely be pooled. However, the pooling of rate ratios also assumes a normal distribution, and this assumption is unlikely to be met. Most articles generate just a moderate number of citations, whereas some seminal articles are cited in abundance. This may have lead to overdispersion and an underestimation of our standard errors and confidence intervals.

Finally, this review has focused on the association between article results and citation, but it has not controlled for potential confounders. It is theoretically possible that positive articles are of a higher quality. If this is the case, then research quality may be the actual determinant of citation frequency rather than research outcome. This would imply that high-quality articles would receive more attention, and this could in fact be beneficial for the scientific process.

However, our analysis has shown that quality was not related to the number of citations (Table 2). This is consistent with previous research that showed no association of citation frequency with research quality (e.g., [62−65]), although there is some evidence for an association with research design [66] which is related to research quality. Only journal impact factor showed a consistent effect on citation. However, we believe this factor to mediate the effect of results on citation (e.g., [15]). It is more likely to publish an article in a high-impact journal if its results are positive, and these positive results may be part of the explanation why high-impact journals and articles receive more citations. All in all, it seems improbable that the impact of the article results on the number of citations, as established in this review, can be explained by other factors.

Citation bias could be avoided by citing only systematic reviews, but these are not always available or suitable. Alternatively, we could cite all the relevant literature studies on a topic but this is not realistic. In fact, even in our systematic review, which presents an exhaustive overview of the literature on citation bias, we may have indulged in selective citation ourselves when it comes to side topics. We have used some references to back up an argument, and we did so to the best of our knowledge but without systematically checking the available literature on each of these side topics. By preceding these ad hoc references with "e.g.", we aimed to clarify that they are merely an example of all the available literature studies. Similarly, journals could adopt the policy to include a statement on the representativeness of the cited literature, similar to statements on funding and author contributions. Such statement could increase the awareness for selective citation, and an increased awareness could reduce its potential harm.

5. Conclusion

This is the first systematic review of citation bias. It brings together all relevant research and quantifies the impact of positive results on the likelihood of being cited in four respective meta-analyses. It shows that citation bias occurs throughout the sciences, mostly in the biomedical field, and irrespective of article selection method, article type, and the way in which a positive article is defined. It further shows that positive articles are cited about twice as often as negative articles.

The negative consequences of citation bias can be similar to those of other questionable research practices like publication bias. They may occur with the best of intentions and their individual effects may be small, but all together, they lead to an overrepresentation of positive findings in the scientific literature. This hampers the scientific process, leads to wrong conclusions and decisions, and will eventually harm the reputation of science.

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Authors' contributions: All authors were involved in the design of this review, read the article, provided feedback, and approved the final version. B.D. is the author of this article, developed and applied the search strategy, performed the article selection and data extraction, corresponded with the authors of included studies, calculated the rate ratios, and conducted the statistical analysis. M.J.E.U. performed the article selection and data extraction and provided feedback on the search strategy and rate ratio calculation. G.M.H.S. obtained funding, provided feedback on the article selection and data extraction, and supervised the research project and its planning. L.M.B. initiated this systematic review, provided detailed feedback on the design and different versions of the article, and was involved in all important decisions. M.P.Z. obtained funding, provided feedback on the search strategy, and supervised the research project and statistical analysis.

Supplementary Data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclinepi.2017.06.002.

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