Scientific Citations Favor Positive Results: A Systematic Review and Meta-analysis

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Abstract

Objective: 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 versus 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 times more often than articles with non-significant results. Articles in which the authors explicitly conclude to have found support for their hypothesis were cited 2.7 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 over-representation of positive results and unfounded beliefs.

Word Count: 197

Keywords

citation bias, outcome bias, meta-analysis, systematic review, questionable research practices, research integrity

Running title

Systematic review of citation bias

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 is known

- This is the first systematic review and meta-analysis on 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.

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 over-representation 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 research misbehavior (4). In order 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.

Materials and Methods

Search strategy

All publications reporting empirical evidence on the association between article results and citation frequency were included. In order to identify these publications, we developed an extensive search strategy. (See Figure S2 in the Supporting Information 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 the majority 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 20. November 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 (BD and MJEU). Disputes were resolved by a third researcher (GMHS).

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 (BD and MJEU).

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 in order to retrieve missing information.

Meta-analyses

Citation data are non-parametric. 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 versus 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, articles with statistically non-significant results as 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, articles with results in the opposite direction as 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 non-significant results or with significant results in the opposite direction are considered as 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 as 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), or else excluded the study from the meta-analysis.

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 and in our review protocol (5). More information on the terminology we use can be found in Figure 1.

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.)

Figure 1. Adopted terminology and levels of research.

Results

Our search strategy identified 47 publications (Figure 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 (Figure S1). 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).

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).

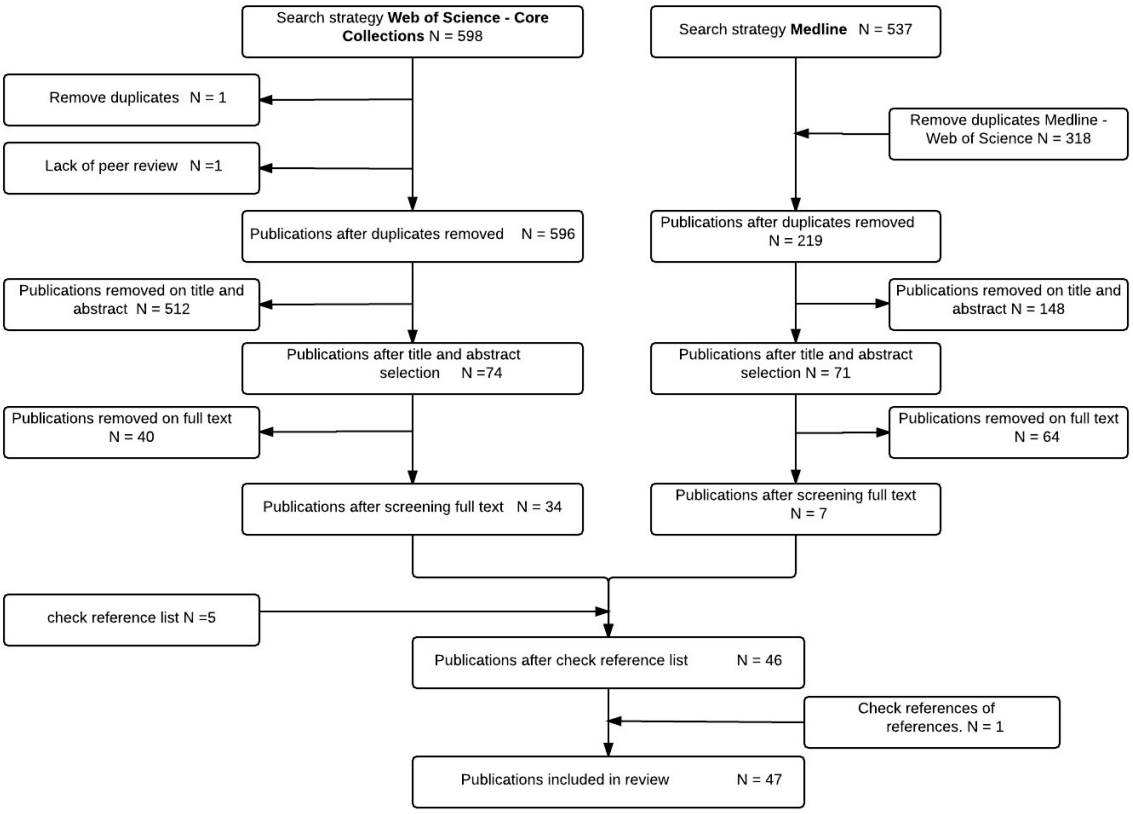

Figure 2. Flow diagram of the article selection process.

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 *	**29 (16)**	**11 (4)**	**12 (8)**	**52 (28)**

Notes: ***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. * 28 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* ($\chi^2(2) = 2.2$, $p = .34$).

The majority 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 non-specific lower-back pain (8) - to broader categories like 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, 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 ($\chi^2(4) = 5.7$, $p = .22$, Table 1).

Apart from scientific discipline, these studies also differ in their article selection approach. 14 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 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 selection methods was not statistically significant ($\chi^2(4) = 1.2$, $p = .88$, Table 1).

Meta-analyses

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

233 Twenty one studies provided sufficient data to calculate a citation rate ratio
234 for *statistical significance*, and to pool their results in a random effects meta-analysis
235 (Figure 3a). This analysis showed that statistically significant articles were cited 1.6
236 times as often as non-significant articles. The heterogeneity was high and the rate
237 ratio varied substantially between studies. Subgroup analyses did not reveal any
238 differences between article selection methods or between article types (Figures S5
239 and S6). A sensitivity analysis, with smaller studies excluded, neither changed the
240 pooled rate ratio nor decreased the heterogeneity (Figure S3). Although the
241 heterogeneity was high and we could not identify its source, almost all studies
242 pointed in the same direction: a citation rate that was higher for articles with
243 significant results.

244 Statistical significance in itself is not enough to imply support for a tested
245 hypothesis, as this would also depend on the direction of the findings. In order to
246 check if some aspects of article results drive citation more than others, additional
247 meta-analyses were performed. These analyses, one on the *direction of results* and
248 one on *hypothesis conformity*, showed similar estimates as the one on statistical
249 significance (with pooled ratio ratios of 2.1 and 1.8 respectively, Figures 3b and 3c).

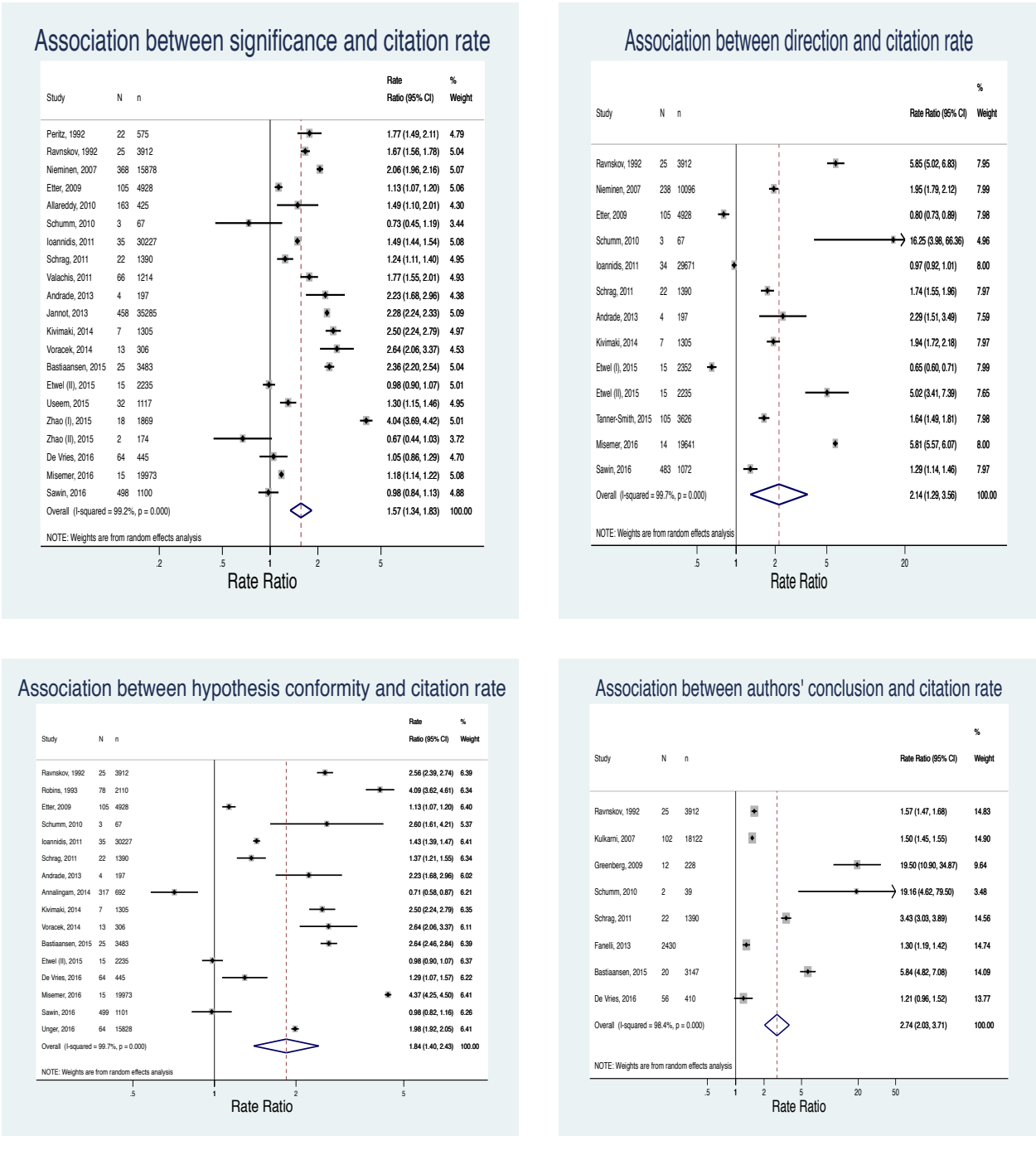

Figure 3. Forest plot of association between article results and citation rate.

NOTES: **CI** Confidence Interval, **N** number of articles, **n** number of citations.

Authors' Conclusion. 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 8 studies on citation bias that looked at the conclusion as stated by the original authors. A meta-analysis including all these 8 studies showed that original articles with a positive conclusion were cited 2.7 times more often (Figure 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. 52% of these studies showed evidence for citation bias (versus 59% of the included studies), while 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 ($\chi^2(2) = 2.4$, $p = .31$). We therefore believe the double citation rates for positive studies to be representative for all published research in our systematic review.

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

295 (JIF, 89%) were more often associated with citation frequency than justifiable
296 determinants such as research quality (17%), sample size (29%) and research
297 design (50%). In some of the above publications, the most recent impact factors
298 were taken for each journal. In these cases, the article of interest was published
299 before the JIF was established, and so the determinant 'JIF' could have been
300 influenced by the dependent variable 'citation frequeny'. Future multivariate
301 analyses are needed to test if this result can be generalized, with JIF retrospectively
302 measured at the moment of publication of the article.
303
304 **Table 2. Determinants of citation**

Determinant	**Number of publications with determinant included in analysis***	**Number of publications with determinant showing a significant effect on citation count**			**Percentage of publications in which determinant shows an effect on citation count****
		Confirms	Mixed / Unclear	Rejects	
Article Results	46 ***	26 ****	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 *****	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 %

Notes: 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)) . * Mostly based on univariate analyses; ** Mixed and unclear results are ignored in the calculation of this percentage. E.g. *Perc*(Article Results) = 26/(26+8)*100% = 76%; *** One publication had measured the outcome and citation frequency of the included articles, but did not analyze the relationship between them; **** One publication confirmed citation bias but in opposite direction, with negative articles being cited more often (7); ***** Only one publication showed an effect of quality-related measures; it showed that lower quality was associated with a higher citation frequency (43).

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 on the relationship between article results and citation has been systematically investigated, and that the magnitude of citation bias has been summarized in a

327 pooled estimate. There is one earlier review, but no search strategy had been
328 specified and only a few publications were included (1).

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

346 The majority of citation bias studies are performed in the biomedical
347 sciences. This might reflect a higher awareness for this kind of biases compared to
348 other disciplines rather than a higher prevalence. In fact, the biomedical field seems
349 generally more advanced in employing initiatives to counter reporting bias and

350 publication bias as reflected in the use of research protocols and preregistration of
351 clinical trials (e.g. (53-55)).

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

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

370 An underlying assumption of our approach to study citation bias, is that
371 citing articles generally agree with the cited articles. This is not necessarily the case.
372 A positive article might also be cited to criticize the message. However, most articles

373 seems to be cited for other reasons than critical appraisal (e.g. (60)). This
374 propagates and reinforces the cited article's message, potentially leading to wrong
375 beliefs if the selection of cited articles is indeed biased.

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

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

394 Finally, this review has focused on the association between article results
395 and citation, but it has not controlled for potential confounders. It is theoretically

396 possible that positive articles are of a higher quality. If this is the case, then research
397 quality may be the actual determinant of citation frequency rather than research
398 outcome. This would imply that high-quality articles would receive more attention,
399 and this could in fact be beneficial for the scientific process.

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

411 Citation bias could be avoided by citing only systematic reviews but these are
412 not always available or suitable. Alternatively, we could cite all the relevant
413 literature on a topic but this is not realistic. In fact, even in our systematic review,
414 which presents an exhaustive overview of the literature on citation bias, we may
415 have indulged in selective citation ourselves when it comes to side topics. We have
416 used some references to back up an argument, and we did so to the best of our
417 knowledge but without systematically checking the available literature on each of
418 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. Likewise, 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.

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 over-representation 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.

Author contributions

All authors were involved in the design of this review, read the manuscript, provided feedback, and approved the final version. BD is the author of this manuscript, 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. MJEU performed the article selection and data extraction and provided feedback on the search strategy and rate ratio calculation. GMHS obtained funding, provided feedback on the article selection and data extraction and supervised the research project and its planning. LMB initiated this systematic review, provided detailed feedback on the design and different versions of the manuscript, and was involved in all important decisions. MPZ obtained funding, provided feedback on the search strategy and supervised the research project and statistical analysis.

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Supporting Information

Text S1. Supporting Information

Figure S1. Levels of research.

Figure S2. Search strategy for systematic review on research outcome and citation count.

Figure S3. Sensitivity analysis: Forest plot of association between statistical significance and citation count, for N≥10.

Figure S4. Sensitivity analysis: Forest plot of association between authors' conclusion and citation count, for N≥10.

Figure S5. Sensitivity analysis: Forest Plot of association between statistical significance and citation count, stratified by article selection method.

Figure S6. Sensitivity analysis: Forest Plot of association between statistical significance and citation count, stratified by type of article.

Figure S7. Funnel plot for association between statistical significance and citation count.

Table S1. Characteristics of publications included in the systematic review

Table S2. Overview of high sample size studies (N≥1000), including specification of source and time frame.

Table S3. Overview of the journal-based studies, including specification of journal and time frame.