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Level of evidence and conflict of interest disclosure associated with higher citation rates in orthopedics

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Abstract

Objective: To identify the scientific and nonscientific factors associated with rates of citation in the orthopedic literature.

Study Design and Setting: All original clinical articles published in three general orthopedics journals between July 2002 and December 2003 were reviewed. Information was collected on variables plausibly related to rates of citation, including scientific and nonscientific factors. The number of citations at 5 years was ascertained and linear regression was used to identify factors associated with rates of citation.

Results: In the multivariate analysis, factors associated with increased rates of citation at 5 years were high level of evidence (22.2 citations for level I or II vs. 10.8 citations for level III or IV; $P = 0.0001$), large sample size (18.8 citations for sample size of 100 or more vs. 7.9 citations for sample size of 25 or fewer; $P < 0.0001$), multiple institutions (15.2 citations for two or more centers vs. 11.1 citations for single center; $P = 0.023$), self-reported conflict of interest disclosure involving a nonprofit organization (17.4 citations for nonprofit disclosure vs. 10.6 citations for no disclosure; $P = 0.027$), and self-reported conflict of interest disclosure involving a for-profit company (26.1 citations for for-profit disclosure vs. 10.6 citations for no disclosure; $P = 0.011$).

Conclusion: High level of evidence, large sample size, representation from multiple institutions, and conflict of interest disclosure are associated with higher rates of citation in orthopedics.

Keywords: Citation rates; Impact factor; Conflict of interest; Level of evidence; Orthopedic surgery; Bibliometrics

1. Introduction

In biomedical research, the wide dissemination of findings to the scientific community is critical. Dissemination occurs primarily through the publication of findings in a peer-reviewed journal. After publication, citation of the original work in subsequent articles further improves dissemination. In this way, the number of times an article is cited may be considered a measure of its overall impact on the field, although this idea is not without its critics [1].

At the present time, journals are often ranked on the basis of their impact factor, a fraction with denominator equal to the number of articles published over a 2-year period and numerator equal to the number of citations received by these articles in the following year [2,3]. In the case of *The Journal of Clinical Epidemiology*, there were 328 articles published in 2006−2007 (denominator) that received 950 citations in 2008 (numerator), which results in the current impact factor of 2.9 [4].

There is reason to believe, however, that rates of citation may be influenced by characteristics other than the impact factor of the publishing journal. Callaham et al. [5] examined articles published in the field of emergency medicine and found that rates of citation were predicted not only by journal impact factor but also by study sample size,

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What is new?

Key finding:
In the multivariate analysis, factors associated with increased rates of citation at 5 years were high level of evidence (22.2 citations for level I or II vs. 10.8 citations for level III or IV; $P = 0.0001$), large sample size (18.8 citations for sample size of 100 or more vs. 7.9 citations for sample size of 25 or fewer; $P < 0.0001$), multiple institutions (15.2 citations for two or more centers vs. 11.1 citations for single center; $P = 0.023$), self-reported conflict of interest disclosure involving a nonprofit organization (17.4 citations for nonprofit disclosure vs. 10.6 citations for no disclosure; $P = 0.027$), and self-reported conflict of interest disclosure involving a for-profit company (26.1 citations for for-profit disclosure vs. 10.6 citations for no disclosure; $P = 0.011$).

What this adds to what is known:
Our results elucidate the factors associated with higher citation rates in the orthopedic literature.

What is the implication and what should change now:
High level of evidence, large sample size, representation from multiple institutions, and conflict of interest disclosure are associated with higher rates of citation in orthopedics.

the presence of a control group, and newsworthiness. More recently, Kulkarni et al. [6] studied articles published in *The New England Journal of Medicine*, the *Journal of the American Medical Association*, and *Lancet* and found high citation rates to be associated with group authorship, larger sample size, specialty field, industry funding, and the reporting of an industry favoring result, in addition to journal impact factor.

Within the field of orthopedics, the factors associated with article citation rates have been examined once previously [7]. Bhandari et al. [7] investigated the factors associated with citation rates among 137 articles published in *Journal of Bone and Joint Surgery: American volume* and found study design to be the only factor associated with subsequent rates of citation. Although this study had many important strengths, it considered articles from only one journal, had a small sample size, and examined the effects of only a small number of predictors.

The purpose of this study was to better characterize the factors associated with citation rates of the orthopedic literature. We build on the prior investigation by Bhandari et al. [7] by analyzing a larger number of articles from three different orthopedic journals over a longer time interval. In addition, a broader range of potential predictors are considered, including scientific factors (level of evidence, controlling, blinding, prospectiveness, and sample size) and nonscientific factors (subspecialty field, number of authors, number of institutions, study location, primary language, self-reported conflict of interest disclosure, and the number of prior publications in frequently cited orthopedic journals by the corresponding author). Our primary outcome measure was the number of citations at 5 years after publication.

2. Methods

2.1. Eligibility criteria

We reviewed all original clinical articles published between July 2002 and December 2003 in the three most frequently cited general orthopedics journals: *The Journal of Bone and Joint Surgery: American volume*, *The Journal of Bone and Joint Surgery: British volume* and *Clinical Orthopaedics and Related Research* [8,9]. During 2002/2003, these journals had impact factors of 2.05/1.92, 1.46/1.50, and 1.21/1.36, respectively [8,9]. Review articles, meta-analyses, case reports, and articles of other types were not considered, and article review was conducted retrospectively.

2.2. Article characteristics

The orthopedic subspecialty field of each article was recorded as adult reconstruction hip, adult reconstruction knee, foot and ankle, hand and wrist, pediatric orthopedics, shoulder and elbow, sports medicine and arthroscopy, spine, trauma, musculoskeletal tumor and metabolic disease, or other.

Study level of evidence was defined according to guidelines published by the American Academy of Orthopaedic Surgeons [10]. For therapeutic studies, which represent the most common type of study in the orthopedic literature, high-quality randomized clinical trials are considered as level I evidence, prospective cohort studies are considered as level II, case–control and retrospective cohort studies are considered as level III, and case series are considered as level IV. Similar criteria exist for nontherapeutic investigations, which include prognostic, diagnostic, and economic/decision analysis studies [10]. *The Journal of Bone and Joint Surgery: American volume* began assigning a level of evidence to each published article in January 2003, so for all articles published in this journal after this date, the assigned level of evidence was recorded. For articles published in *The Journal of Bone and Joint Surgery: British volume* and *Clinical Orthopaedics and Related Research*, as well as articles published in *The Journal of Bone and Joint Surgery: American volume* before January 2003, level of evidence was assigned by an individual with advanced training in clinical epidemiology (K.O.) according to established guidelines [11]. The reliability of this assessment has previously been reported [12]. In addition, the presence or absence of controlling, blinding, and prospectiveness, as

well as sample size were assessed for all studies by this same individual.

All articles were reviewed by a second investigator (J.L.T.) to determine the number of authors associated with each article. Author affiliations were examined to determine the number of institutions associated with each article. Based on the address of the corresponding author, study location was classified into one of the five regions: United States; Canada; Europe and Australia; Asia and the Middle East; or Latin America, the Caribbean, and Africa. Primary language was classified as English or non-English, depending on whether English was an official language in the country of the corresponding author.

Self-reported conflict of interest disclosures were reviewed and classified as being related to a for-profit company (i.e., industry) or a nonprofit organization (i.e., nonindustry). All reported conflicts were considered, including research support, royalties, stock options, and consultant/employee status. To determine the number of prior publications in frequently cited orthopedic journals by the corresponding author, PubMed was used to identify all articles published in the five most frequently cited general orthopedics journals (*The Journal of Bone and Joint Surgery: American volume*, *The Journal of Bone and Joint Surgery: British volume*, *Clinical Orthopaedics and Related Research*, *The Journal of Orthopaedic Research*, and *Acta Orthopaedica*) [13] by the corresponding author at the time of article publication.

2.3. Number of citations at 5 years

The Science Citation Index Expanded is an online database maintained by ISI Web of Knowledge, which records citation information on articles published in a wide variety scientific journals, using data drawn from "approximately 10,000 scholarly and technical journals and conference proceedings from more than 3,300 publishers in over 60 countries" [14]. Although other citation databases do exist at this point in time [15], we chose to use the Science Citation Index Expanded because it is has the longest track record and has been used successfully by a number of similar studies in the past [5−7,16].

To determine the number of citations at 5 years, the Science Citation Index Expanded database was queried during the month of February 2009. In particular, a cited reference search was conducted for each article to determine the number of times each article had been cited in the scientific literature in the 5 years after publication. The initial query was performed by one investigator (B.O.N.) using the year of publication as well as the first author's last name and first initial followed by an asterisk (so that articles indexed with a middle initial would be detected as well). In the case of articles not initially identified in the database ($N = 6$), additional searches were conducted by a second independent investigator (K.O.) to confirm absence from the database. Articles confirmed to be absent from the database ($N = 6$) were classified as having zero citations.

To determine the rate of article citation over time, we selected the first 10 articles published in July 2002 for each journal, which yielded a total of 30 articles. For each article, a cited reference search was conducted by one investigator (J.L.T.) and the number of times it was cited in each of the 60 months between August 2002 and July 2007 was recorded. The counts obtained for these 30 articles were averaged to derive the trendline.

2.4. Data analysis

For each variable, the mean number of citations at 5 years as well as the 95% confidence interval (95% CI) were calculated. In the multivariate analysis, multiple linear regression via a general linear model was used to simultaneously adjust for all variables (publishing journal, subspecialty field, level of evidence, controlling, blinding, prospectiveness, sample size, number of authors, number of institutions, study location, primary language, conflict of interest disclosure, and number of prior publications in frequently cited orthopedic journals by the corresponding author). Categorical variables were coded as one if the variable of interest was present or zero if the variable of interest was absent. Because preliminary analysis indicated that the distribution of the dependent variable (number of citations at 5 years) was positively skewed (see Fig. 1), a log-transformation was performed to satisfy the normality assumption (Fig. 2). To account for the fact that some articles had zero citations (and the log of zero is undefined), the final term modeled in the multivariate analysis was ln(citations + 1). All assumptions of linear regression were met by this model, including lack of error term correlation (Durbin−Watson statistic = 1.97), independence and constant variance of error terms (homoscedasticity; $P = 0.67$), and normal distribution of error terms (Shapiro−Wilks statistic $W = 0.996$, $Pr < W = 0.1392$). All tests were two sided and $P < 0.05$ was considered statistically significant. Statistical analysis was performed using SAS (SAS 9, SAS Inc., Cary, NC).

3. Results

Between July 2002 and December 2003, there were 661 original clinical articles published in the three journals examined. Level of evidence was generally low, with more than half (55.8%; 369/661) of studies labeled as level IV evidence. The United States and Europe/Australia accounted for three-quarters of all articles published (75.5%; 499/661). Approximately one-quarter of articles disclosed a conflict of interest (26.0%; 172/661), with nonprofit sources being more common than for-profit sources (Table 1).

In the 5 years following publication, nearly all articles were cited at least once (654/661; 98.9%). Although most

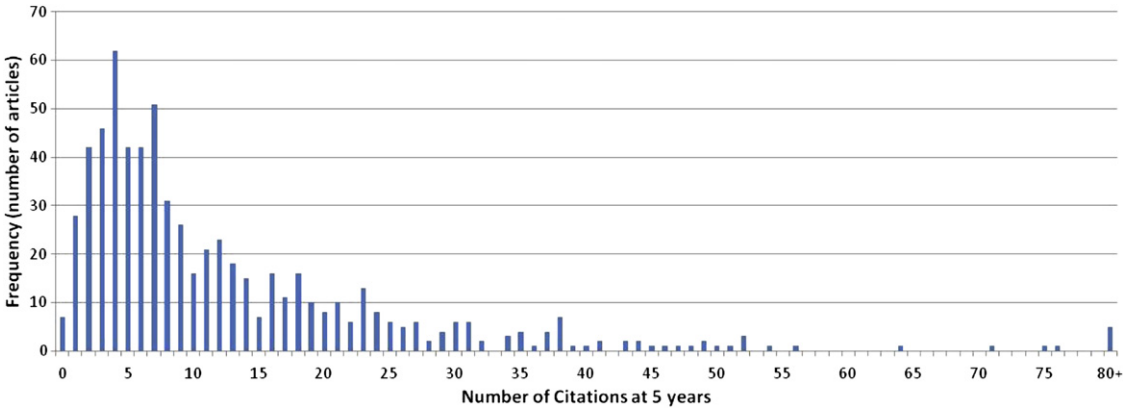

Fig. 1. Distribution of the 5-year citation rate. In the 5 years following publication, most articles (59.5%) were cited 10 times or fewer, whereas a small percentage (12.1%) was cited more than 25 times. Data from Science Citation Index Expanded.

articles (393/661; 59.5%) were cited 10 times or fewer, a small percentage (12.1%; 80/661) was cited more than 25 times, with the maximum number of citations being 194. The distribution of the 5-year citation rate was positively skewed with mode 4, median 8, mean 13.1, and standard deviation 16.6 (Fig. 1). There were few citations in the first year following publication, but the rate of article citation was otherwise relatively constant over time (Fig. 3).

In the multivariate analysis, factors associated with increased rates of citation at 5 years were publishing journal (19.5 citations for *The Journal of Bone and Joint Surgery: American volume* vs. 8.1 citations for *Clinical Orthopaedics and Related Research*; $P < 0.0001$), high level of evidence (22.2 citations for Level I or II vs. 10.8 citations for Level III or IV; $P = 0.0001$), large sample size (18.8 citations for sample size of 100 or more vs. 7.9 citations for sample size of 25 or fewer; $P < 0.0001$), multiple institutions (15.2 citations for two or more centers vs. 11.1 citations for single center; $P = 0.023$), self-reported conflict of interest disclosure involving a nonprofit organization (17.4 citations for nonprofit disclosure vs. 10.6 citations for no disclosure; $P = 0.027$), and self-reported conflict of interest disclosure involving a for-profit company (26.1 citations for for-profit disclosure vs. 10.6 citations for no disclosure; $P = 0.011$). In addition, articles in the subspecialty field of sports medicine and arthroscopy were cited at a significantly higher rate ($P = 0.0002$), whereas pediatric orthopedic articles were cited at a significantly lower rate ($P = 0.038$) (Table 2).

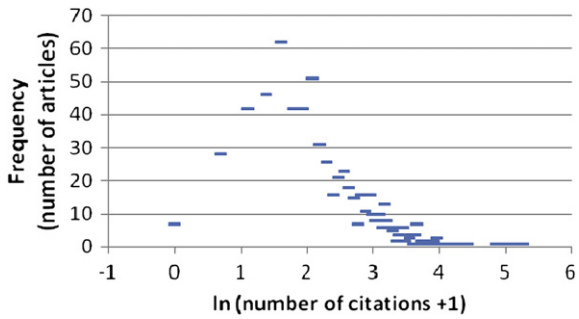

Fig. 2. Distribution of ln (citations +1). The distribution of ln(citations + 1) satisfies the normality assumption and was modeled in the multivariate analysis.

4. Discussion

In this observational study of articles published in three frequently cited general orthopedics journals, factors associated with a greater number of citations at 5 years were high level of evidence, large sample size, representation from multiple institutions, and self-reported disclosure of a conflict of interest involving a nonprofit organization or for-profit company. Articles from the subspecialty field of sports medicine and arthroscopy had significantly higher rates of citation, whereas pediatric orthopedic articles were cited less often.

Our finding that level of evidence was associated with higher rates of citation is in agreement with prior research conducted in the field of orthopedic surgery. Bhandari et al. [7] studied 137 articles published in *The Journal of Bone and Joint Surgery: American volume* in 2000 and found that randomized controlled trials were cited more than twice as often as observational studies. Studies of higher level of evidence have greater methodological safeguards against bias and provide better information to guide clinical care. It is encouraging to see that these studies are having a disproportionately large impact on the field at the present time.

The other scientific factor we found to be significantly associated with rates of citation was sample size. Prior studies in other fields have found sample size to be a significant predictor of citation rates, including an analysis of three leading general medicine journals by Kulkarni et al. [6] and a study of the emergency medicine literature by Callaham et al. [5]. Although larger sample size does not necessarily indicate better research, it may serve as a surrogate for sample size sufficiency (i.e., power), which could

Table 1
Article characteristics

Variables	Number of articles (% of total)
Journal	
Clinical Orthopaedics and Related Research	187 (28.3)
The Journal of Bone and Joint Surgery: British volume	223 (33.7)
The Journal of Bone and Joint Surgery: American volume	251 (38.0)
Subspecialty field	
Adult reconstruction hip	132 (20.0)
Adult reconstruction knee	99 (15.0)
Foot and ankle	31 (4.7)
Hand and wrist	23 (3.5)
Pediatric orthopedics	75 (11.4)
Shoulder and elbow	70 (10.6)
Sports medicine and arthroscopy	24 (3.6)
Spine	37 (5.6)
Trauma	94 (14.2)
Tumor and metabolic disease	59 (8.9)
Other	17 (2.6)
Level of evidence	
I	82 (12.4)
II	54 (8.2)
III	98 (14.8)
IV	369 (55.8)
N/A	58 (8.8)
Controlling	
No	465 (70.4)
Yes	196 (29.7)
Blinding	
No	644 (97.4)
Yes	17 (2.6)
Prospectiveness	
No	449 (67.9)
Yes	212 (32.1)
Sample size	
25 or fewer	204 (30.9)
26–99	258 (39.0)
100 or more	199 (30.1)
Number of authors	
1	8 (1.2)
2	77 (11.7)
3	121 (18.3)
4	154 (23.3)
5	123 (18.6)
6	123 (18.6)
7 or more	55 (8.3)
Number of institutions	
1	340 (51.4)
2	199 (30.1)
3	73 (11.0)
4 or more	49 (7.4)
Study location	
United States	251 (38.0)
Canada	21 (3.2)
Europe and Australia	248 (37.5)
Asia and the Middle East	136 (20.6)
Latin America, the Caribbean, and Africa	5 (0.8)
Primary language	
Non-English	262 (39.6)
English	399 (60.4)
Conflict of interest disclosure[a]	
None	489 (74.0)
Involving a nonprofit entity	131 (19.8)
Involving a for-profit company	78 (11.8)
Number of prior publications in frequently cited orthopedic journals by the corresponding author	
0	138 (20.9)
1–9	325 (49.2)
10 or more	198 (30.0)
Total	661 (100.0)

Abbreviation: N/A, not applicable.
[a] Thirty-seven studies reported both for-profit and nonprofit conflicts of interest.

be considered a quality measure. Controlling, blinding, and prospectiveness were not predictive of citation rates in the multivariate analysis, which may have been due in part to residual confounding by level of evidence.

To our knowledge, the influence of scientific collaboration on rates of article citation has been studied only once previously. In particular, Figg et al. [16] examined articles published in six leading scientific journals—*The New England Journal of Medicine*, the *Journal of the American Medical Association*, *Lancet*, *Cell*, *Science*, and *Nature*—and found that article citation rates correlated significantly with the number of institutions as well as the number of authors associated with each article. We did not detect an association between number of authors and number of citations, but we did find multicenter studies to receive significantly more citations than studies conducted at a single institution. Authors who are open to collaboration with investigators from other institutions may be able to produce articles that have a higher impact on the field.

The association between conflict of interest disclosure and citation rate has not been analyzed previously in the field of orthopedics, but it has been examined before in the field of internal medicine. Kulkarni et al. [6] analyzed 328 articles published in three leading general medicine journals and found industry funding to be associated with a statistically significant increase in article citation rate. In our study, self-reported disclosure of a conflict of interest involving a nonprofit organization or for-profit company was associated with a higher rate of citation. Although the specific explanations for this finding are unknown, it is possible that researchers who secure external funding may be able to publish articles that are superior and, therefore, more likely to be cited. However, further investigation is required before definitive conclusions can be drawn.

In the multivariate analysis, a focus on the subspecialty field of sports medicine and arthroscopy emerged as one of

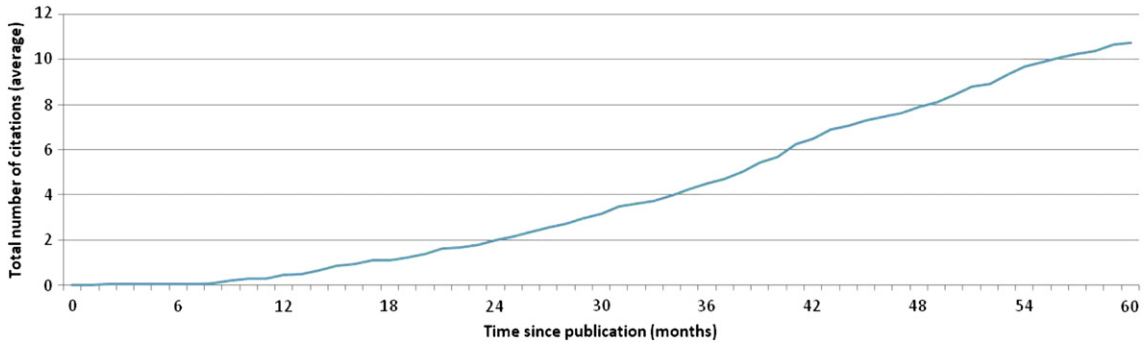

Fig. 3. Number of citations over time. To determine the rate of article citation over time, we selected the first 10 articles published in July 2002 for each journal, which yielded a total of 30 articles. For each article, the Science Citation Index Expanded was queried to determine the cumulative number of times each article had been cited in the 60 months between August 2002 and July 2007. These values were averaged to derive the trendline. There were few citations in the first year following publication, but the rate of article citation was otherwise relatively constant over time.

the most highly significant predictors of increased citation rates. Articles in pediatric orthopedics, on the other hand, were significantly less likely to be cited. The specific reasons for these findings are unclear but may relate to the number of practitioners and the volume of research being conducted in each subfield. This is a finding that is also deserving of further investigation.

The results of our investigation must be considered within the context of its study design. Our study benefits from the fact that it had a large sample size and considered three leading general orthopaedics journals, which may make our findings more generalizable to the orthopaedic literature as a whole. In addition, we controlled for a wide variety of scientific and non-scientific variables, which

Table 2
Article citation rates

Variables	*N*	Mean number of citations at 5 yrs (95% CI)	Multivariate regression coefficient[a] (95% CI)	Multivariate *P*-value
Journal				
Clinical Orthopaedics and Related Research[b]	187	8.1 (6.9, 9.3)	—	—
The Journal of Bone and Joint Surgery: British volume	223	10.1 (8.0, 12.1)	+0.13 (−0.04, 0.29)	0.1358
The Journal of Bone and Joint Surgery: American volume	251	19.5 (17.0, 21.9)	**+0.57 (0.42, 0.72)**	**<0.0001**
Subspecialty field				
Adult reconstruction hip[b]	132	14.2 (11.8, 16.6)	—	—
Adult reconstruction knee	99	13.5 (10.3, 16.7)	−0.03 (−0.23, 0.17)	0.7763
Foot and ankle	31	14.9 (9.1, 20.8)	−0.08 (−0.36, 0.22)	0.6170
Hand and wrist	23	8.3 (4.4, 12.2)	−0.24 (−0.58, 0.10)	0.1603
Pediatric orthopedics	75	8.0 (6.1, 9.9)	**−0.23 (−0.45, −0.01)**	**0.0380**
Shoulder and elbow	70	11.6 (9.4, 13.7)	−0.07 (−0.29, 0.15)	0.5379
Sports medicine and arthroscopy	24	33.4 (15.9, 51.0)	**+0.63 (0.30, 0.96)**	**0.0002**
Spine	37	12.2 (7.8, 16.6)	−0.01 (−0.28, 0.26)	0.9372
Trauma	94	15.9 (11.3, 20.4)	+0.11 (−0.09, 0.30)	0.2992
Tumor and metabolic disease	59	7.4 (5.9, 8.9)	−0.08 (−0.32, 0.16)	0.4997
Other	17	11.6 (7.1, 16.2)	−0.10 (−0.48, 0.28)	0.6124
Level of evidence[c]				
III or IV[b]	467	10.8 (9.9, 11.8)	—	—
I or II	136	22.2 (17.3, 27.1)	**+0.29 (0.12, 0.47)**	**0.0010**
Controlling				
No[b]	465	11.5 (10.4, 12.6)	—	—
Yes	196	16.8 (13.4, 20.1)	+0.09 (−0.06, 0.23)	0.2273
Blinding				
No[b]	644	12.8 (11.7, 14.0)	—	—
Yes	17	22.4 (−0.6, 45.4)	+0.13 (−0.24, 0.50)	0.4777
Prospectiveness				
No[b]	449	11.8 (10.7, 12.9)	—	—
Yes	212	15.7 (12.6, 18.9)	−0.13 (−0.28, 0.03)	0.1122

(*Continued*)

Table 2
Continued

Variables	*N*	Mean number of citations at 5 yrs (95% CI)	Multivariate regression coefficient[a] (95% CI)	Multivariate *P*-value
Sample size				
25 or fewer[b]	204	7.9 (6.9, 9.0)	—	—
26–99	258	12.7 (10.9, 14.6)	**+0.16 (0.02, 0.30)**	**0.0305**
100 or more	199	18.8 (15.7, 22.0)	**+0.36 (0.20, 0.52)**	**<0.0001**
Number of authors				
1–4[b]	360	11.6 (10.4, 12.7)	—	—
5 or more	301	14.9 (12.5, 17.3)	+0.01 (−0.11, 0.14)	0.8169
Number of institutions				
1[b]	340	11.1 (9.6, 12.5)	—	—
2 or more	321	15.2 (13.2, 17.3)	**+0.14 (0.02, 0.25)**	**0.0231**
Study location				
Non-United States[b]	410	11.3 (9.9, 12.8)	—	—
United States	251	15.9 (13.6, 18.3)	+0.01 (−0.18, 0.19)	0.9217
Primary language				
Non-English[b]	262	11.1 (9.4, 12.7)	—	—
English	399	14.4 (12.6, 16.2)	+0.00 (−0.16, 0.17)	0.9714
Conflict of interest disclosure				
None[b]	489	10.6 (9.6, 11.7)	—	—
Involving a nonprofit entity	131	17.4 (14.9, 19.8)	**+0.17 (0.02, 0.32)**	**0.0270**
Involving a for-profit company	78	26.1 (18.9, 33.3)	**+0.25 (0.06, 0.44)**	**0.0105**
Number of prior publications in frequently cited orthopedic journals by the corresponding author				
0[b]	138	11.1 (8.6, 13.7)	—	—
1–9	325	13.3 (11.4, 15.2)	+0.07 (−0.08, 0.22)	0.3544
10 or more	198	14.1 (11.8, 16.4)	+0.11 (−0.06, 0.28)	0.2040

Abbreviations: CI, confidence interval; N/A, not applicable.

Values presented in bold indicate statistical significance ($P < .05$).

[a] Positive regression coefficients indicate factors associated with higher citation rates, whereas negative regression coefficients indicate factors associated with lower citation rates. The regression coefficients are otherwise not readily interpretable given that the dependent variable (number of citations at 5 yrs) was transformed to allow linear regression.

[b] Reference category.

[c] Excludes articles with level of evidence categorized as N/A ($N = 58$).

decreases the likelihood that the observed results were unduly influenced by confounding.

Our study does have its limitations, however. Given that conflict of interest disclosures were self-reported, it is possible that some conflicts may have been underreported (either intentionally or unintentionally) [17]. The fact that we chose not to control for self-citation may be considered a limitation of our study, although prior research has suggested that rates of self-citation do not correlate significantly with overall citation rates within the field of orthopedics ($P > 0.05$) [7]. Finally, it should be emphasized that although our results demonstrate association between certain factors and subsequent rates of citation, they do not prove causation.

For authors wishing to publish articles that will have a substantial impact on the field, our study provides some important clues. In addition to seeking publication in a high-impact journal, researchers should aim to conduct multicenter studies with high level of evidence and large sample size. The acquisition of external funding—whether from a nonprofit organization or a for-profit company—may also allow one to conduct research that is more likely to be cited, although this is a finding that requires further investigation.

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