

# Publication Metrics and Subject Categories of Biomechanics Journals

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## ABSTRACT

Research in interdisciplinary fields like biomechanics is published in a variety of journals whose visibility depends on bibliometric indexing that is often driven by citation analysis of bibliometric databases. This study documented variation in publication metrics and research subject categories assigned to 14 biomechanics journals. Authors, citation, and citation rate (CR) were collected for the top 15 cited articles in the journals retrieved from the *Google Scholar* service. Research subject categories were also extracted for journals from three databases (*Dimensions*, *Journal Citation Reports*, and *Scopus*). Despite the focus on biomechanics for the journals studied, these biomechanics journals have widely varying CR and subject categories assigned to them. There were significant ( $p=0.001$ ) and meaningful (77-108%) differences in median CR between average, low, and high CR groups of these biomechanics journals. Since CR are primary data used to calculate most journal metrics and there is no one biomechanics subject category, field normalization for journal citation metrics in biomechanics is difficult. Care must be taken to accurately interpret most citation metrics of biomechanics journals as biased proxies of general usage of research, given a specific database, time frame, and area of biomechanics research.

**Keywords:** citation, field, impact, ranking, research, searching

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## 1. INTRODUCTION

Biomechanics is a specialized scientific field integrating biology and physics. These two parent disciplines have a long history, while biomechanics is a relatively recently recognized term and field, with the *Journal of Biomechanics* first appearing in 1968. The utility of biomechanics in understanding performance and injury in a diversity of living things and movements has resulted in the establishment of additional biomechanics journals and biomechanics research reports appearing in a wide variety of multi-disciplinary or other-field journals. In addition, no scientific field is completely isolated, and so large electronic databases have increased across-field visibility of biomechanics research and citations. Searching for knowledge, therefore, relies on searching numerous electronic bibliometric database services (e.g., *CINAHL*, *Dimensions*, *Engineering Source*, *Google Scholar [GS]*, *Medline*, *Scopus*, *Web of Science [WoS]*) for peer-reviewed journal articles (Bar-Ilan, 2018; De Groote & Raszewski, 2012; Lascar & Barnett, 2009; Martín-Martín et al., 2021; Meho & Yang, 2007; Ramos-Remus et al., 1994).

The visibility of biomechanics research depends on the indexing of journal articles in databases and the accuracy of the associated search engines (Elkins et al., 2010; Gusenbauer & Haddaway, 2020; Prancutè, 2021) and promotion of ranked records (Delgado-López-Cózar & Cabezas-Clavijo, 2013; Yamato et al., 2018). Electronic indexing of journals and the articles they publish has been increasingly driven by analysis of citations and citation networks (Garfield, 2006). Journal citation metrics, however, must be field normalized because of large variation in citation patterns across diverse scholarly disciplines (Declaration on Research Assessment [DORA], 2015; Hicks et al., 2015; Seglen, 1997; Waltman, 2016). While field normalization of citation measures is an established principle of bibliometrics/scientometrics/informetrics, operationalization of the most appropriate field reference values remains an unsettled issue (Haunschild et al., 2022; Haunschild & Bornmann, 2022; Leydesdorff & Bornmann, 2016). This present article will use the term *bibliometrics* to refer to all three of the science of knowledge fields noted that focus on these important issues. The limited bibliometric research on biomechanics journals warrants further examination to understand the visibility and interpretation of citation-based metrics of different areas of biomechanics research.

Field normalization is usually based on the assignment of research subject categories to journals indexed by da-

tabases, so that journal citation metrics in a field can be scaled to typical values of that field and timeframe. There is considerable variation, however, in how categories are assigned (Bornmann & Marx, 2015; Haunschild et al., 2022; Waltman & van Eck, 2019) and the number (12 to thousands) of subject categories created. There is also variation in results based on the time frame of interest (research front vs. long-term research taxonomies) and computational power (Klavans & Boyack, 2017), article types (Haunschild & Bornmann, 2022), and index effects (Leydesdorff & Bornmann, 2016). Unfortunately, “biomechanics” does not appear as a subject category in major electronic databases and biomechanics has only recently been added to the Classification of Instructional Program codes by the National Center for Education Statistics (U.S. Department of Education’s National Center for Education Statistics, 2020). There is little known about bibliometrics of biomechanics journals or subject categories assigned to them by bibliometric databases (Zadpoor & Nikooyan, 2011).

### 1.1. Bibliometrics of Biomechanics

Knudson and Chow (2008) reported that perceptions of quality or impact of 62 journals publishing biomechanics research by American Society of Biomechanics (ASB) members varied by research interest. A study of publication metrics and the *Journal Citation Reports (JCR)* impact factor (IF) of fourteen biomechanics journals over eight years indicated differences in the IF between seven *JCR* subject categories, and there was a slower increase in IF in biomechanics journals compared to other biomedical journals (Zadpoor & Nikooyan, 2011). In this study the biomechanics journals had a mean IF similar (1.2) to sport sciences journals, but lower than for typical biomedical engineering/biomaterials (2-3) and somewhat higher than for mechanical engineering/robotics (0.6-1.2) journals. This mean inflation (0-22% annually) and variation (coefficient of variation [CV]=12-21%) of the IF and four other citation metrics was recently confirmed for 14 biomechanics journals in a recent study (Knudson & Quimby, 2023). Given the well-known differences in citation patterns between various sciences and support of this in perceptions of journals by ASB members (Knudson & Chow, 2008) and *JCR* subject categories (Zadpoor & Nikooyan, 2011), additional study was needed within biomechanics journals of likely differences in citation patterns. Assignment of numerous subject categories and overlap across different disciplines are considered evidence of interdisciplinarity of journals (Morillo et al.,

2001).

Field normalization based on citation rates for an interdisciplinary field like biomechanics may be an even greater challenge given research may be published in biological, natural, medical, or many applied science journals. The ASB currently requests that members select from five primary discipline categories: biological sciences, engineering and applied science, exercise and sports science, ergonomics and human factors, and health sciences. This creates challenges to field journal visibility and field normalization due to wide variation in citation rates in numerous subject categories. For example, a study of a similar interdisciplinary field reported substantial differences in subject categories and citation patterns in *JCR* for 100 kinesiology-related journals (Knudson, 2022a).

### 1.2. Objectives

This current study documented variation in publication metrics of top-cited articles between different biomechanics journals. A secondary purpose was to document the variation of research subject categories assigned to these journals by databases and to determine if there were differences in citation metrics across categories.

### 1.3. Hypotheses

It was hypothesized that there would be differences in citation and publication metrics of top-cited articles across

biomechanics journals associated with different subject categories assigned by bibliometric databases. These data will be important in potential field normalization of biomechanics research and in understanding how databases categorize research in the field.

## 2. METHODOLOGY

### 2.1. Journals and Subject Categories

Fourteen journals publishing primarily biomechanics research in the English language were selected for this study (Table 1). This systematic sample was based on previous studies (Knudson & Quimby, 2023; Zadpoor & Nikooyan, 2011), bibliometric indexing, and Internet visibility, and strove to include both long-standing (*Journal of Biomechanics*: 1968-) and more recently established biomechanics-focused journals (*International Biomechanics*: 2014-). Ergonomics/human factors journals related to biomechanics were excluded from the sample because of the large number of highly-cited articles in these journals focusing on psychology rather than biomechanics. The focus on 14 biomechanics-specific journals like previous research (Knudson & Quimby, 2023; Zadpoor & Nikooyan, 2011) avoided different citation patterns and subject categories seen in studies of large samples of multidisciplinary or other journals that only occasionally publish biomechanics-related research (Knudson & Chow, 2008).

**Table 1.** Median citation rate (CR) and age of top cited articles between three groups of biomechanics journals

Group	Journal	CR	Journal	Age
High	<i>Gait &amp; Posture</i>	66	<i>Journal of Biomechanics</i>	29
	<i>Journal of Biomechanics</i>	54	<i>Journal of Applied Biomechanics</i>	25
	<i>Clinical Biomechanics</i>	52	<i>Sports Engineering</i>	21
	<i>J Electromyography &amp; Kinesiology</i>	41	<i>Clinical Biomechanics</i>	20
Average	<i>Medical Engineering &amp; Physics</i>	38	<i>Gait &amp; Posture</i>	20
	<i>Journal of Biomechanical Engineering</i>	23	<i>J Electromyography &amp; Kinesiology</i>	20
	<i>Biomechanical Modeling Mech</i>	21	<i>Biomechanical Modeling Mech</i>	16
	<i>Comp Meth Biomech Biomed Eng</i>	34	<i>Comp Meth Biomech Biomed Eng</i>	16
	<i>Journal of Applied Biomechanics</i>	18	<i>Medical Engineering &amp; Physics</i>	16
	<i>Sports Biomechanics</i>	14	<i>Sports Biomechanics</i>	15
Low	<i>J Mechanics in Medicine &amp; Biology</i>	9	<i>J Biomechanical Science &amp; Engineering</i>	14
	<i>Sports Engineering</i>	5	<i>J Mechanics in Medicine &amp; Biology</i>	11
	<i>J Biomechanical Science &amp; Engineering</i>	4	<i>Journal of Biomechanical Engineering</i>	10
	<i>International Biomechanics</i>	3	<i>International Biomechanics</i>	7

Age=2023-year of publication (yr) and CR=Citations/Age (C/yr).

The consistency of research subject category classification of these journals was examined by extracting the second level subject categories assigned by three bibliometric databases: *Dimensions*, *JCR*, and *Scopus* (Table 2). Journals were searched for using the “Source Title” function in the free version (<https://www.dimensions.ai/products/free>) of the *Dimensions* database. The “Research Categories” assigned by the database and number of articles indexed were recorded. A university subscription to *JCR* was searched for the subject “Category” associated with the journal titles, and *Scopus* second level categories under “Subject Area and Category” were identified by searching journal titles in *SCImago Journal & Country Rank* (<https://www.scimagojr.com>) that use *Scopus* data.

## 2.2. Database and Measures

*GS* service was selected for journal publication metrics in this study given its superior coverage of peer reviewed journal articles over other subscription databases in all fields of science (Delgado-López-Cózar & Cabezas-Clavijo, 2013; Halevi et al., 2017; Harzing & Alakangas, 2016; Martín-Martín et al., 2018; 2021; Meho & Yang, 2007). This avoids bias in indexing/coverage of the two (*WoS*

and *Scopus*) major subscription databases (Pranckutė, 2021); however, this requires extra time in manual review and cleaning of records returned from searches. The high ( $r=0.78-0.99$ ) associations of citations and subsequent citation metrics for journal articles and authors between *GS* and *WoS* and *Scopus* (De Groot & Raszewski, 2012; Franceschet, 2010; Knudson, 2015a; 2022b; 2023; Martín-Martín et al., 2018; Renjith & Pradeepkumar, 2021) also allow for the conceptual replication and extension of initial research on variation in citation metrics across subject or topical interest areas within biomechanics (Knudson & Chow, 2008; Knudson & Quimby, 2023; Zadpoor & Nikooyan, 2011).

The publication metrics examined in this study focused on areas where previous bibliometrics have reported disciplinary differences: authorship, citations, and field speed/time. The names and number authors of the top 15 cited articles were recorded, and total *GS* citations (*C*) and the year of publication of each article (*Year*) were collected. Two additional variables calculated from these variables were article age ( $\text{Age}=2023-\text{Year}$ ) and citation rate (citation rate [*CR*]= $C/\text{Age}$ ). Article citation rates determine most journal metrics (e.g., CiteScore, IF) and Age was available

**Table 2.** Second level research subject categories assigned to 14 biomechanics journals by three databases

<i>Dimensions</i>	n	<i>Journal Citation Reports</i>	n	<i>Scopus</i>	n
Aerospace Eng	1	Biophysics	4	Bioengineering	2
Allied Health & Rehab	8	Eng, Biomedical	9	Biomedical Eng	7
Applied Mathematics	1	Comp Sci, Interdisc Appl	2	Biophysics	6
Biomed & Clin Sciences	4	Neurosciences	2	Biotechnology	1
Biomed Eng	9	Orthopedics	2	Computer Science Applications	2
Civil Eng	2	Physiology	1	Human Computer Interaction	1
Clinical Sciences	3	Rehabilitation	1	Mechanical Eng	2
Cont Eng, Mechtron & Rob	4	Sport Sciences	6	Mechanics of Materials	1
Engineering	10			Medical [misc]	1
Fluid Mech & Thermal Eng	4			Modeling & Simulation	2
Health Sciences	10			Neurology [clinical]	1
Materials Eng	1			Neuroscience [misc]	1
Mathematical Sciences	1			Orthopedics & Sports Medicine	7
Physical Sciences	1			Phy Ther, Sports Ther & Rehab	2
Public Health	1			Physiology [medical]	1
Sports Science & Exercise	9			Rehabilitation	4
				Sports Science	7

Numerals indicate the number of times each subject category was assigned to the 14 biomechanics journals in the study. Only 12 of the journals were indexed in *Journal Citation Reports* and were able to receive a subject category classification from that database.

for all journals, unlike the *JCR Cited Half-Life*. CR also avoids well-known biases in cites per citable articles ratios, like the journal IF that have serious biases and are weakly correlated with individual articles they publish (Abramo et al., 2023; Seglen, 1997; Zhang et al., 2017). The history of publication of each journal (History=2023-Year of first issue) was also recorded.

The “Return articles published in” tool of the advanced search option of *GS* was used for each journal title and variations of journal title. Numerous searches were conducted, and data were extracted from the top 15 cited articles of each journal. The page rank algorithm of *GS* will return up to 1,000 records of any search, and articles are generally listed in descending order by total citations. The investigator reviewed the top 50 returned records to ensure the top 15 records by total citations were obtained. Searches were completed by February 26, 2023.

This study used the top 15 cited articles for each journal following the standard bibliometric practice of focusing on the top percentiles (e.g., 5 or 10%) of citation metrics (Bornmann & Marx, 2014; 2015). There are very strong positive skews of citations and a large percentage of uncited articles in all scholarly fields (Seglen, 1992; 1997; Stern, 1990; Zhang et al., 2017), including biomechanics (Knudson, 2015a; 2015b; 2023), meaning citations to journals are dominated by a small percentage of highly-cited articles. Recent research also indicates that the importance of citation elites is growing in importance (Reardon, 2021). Therefore, this study focused on total citations and citation rates of the top 15 cited articles as a less biased and representative estimate of likely variation and differences in publication metrics across areas of research interest within biomechanics.

2.3. Data Analysis

Extracted data were entered into Excel and rechecked before importing into *JMP Pro 14* (SAS Institute, Cary, NC) for statistical analysis. Descriptive data were calcu-

lated for publication metrics across (n=210) all journals and by journal. The research subject categories assigned to these journals were compiled (Table 2).

Given the lack of normality from the large positive skew (Table 3) of publication metrics, subsequent comparison of across journals and subject categories was based on non-parametric Kruskal-Wallis tests. Significant ( $p<0.025$ ) effects of journal on primary dependent variables (CR and Age) were followed up with comparison across journals split into three groups (High, Average, Low) based on median CR. The three groups were based on rank order of the medians into the top four, middle six, and lowest four journals. Subject categories assigned to these groups were qualitatively compared to explore differences in citation patterns and interdisciplinary in biomechanics journals. Potential interaction of journal history with field speed was examined by correlation of Age with History. The nonparametric statistical analyses precluded effect size calculation, so size of effects were qualitatively based on studies of variation of citation metrics in biomechanics journals (Knudson & Quimby, 2023; Zadpoor & Nikooyan, 2011).

3. RESULTS

All publication metrics were not normally distributed ( $W=0.68-0.96, p<0.001$ ), showing positive skews ( $\gamma=0.89-3.0$ ) and large variability ( $CV=43-130%$ ) across all biomechanics journals (Table 3). Typical (median and mean) Authors (3 and 4) and Age values for highly-cited articles (17 and 17.3) were less variable across journals than were C or CR. Consistent with this variability, the biomechanics journals were classified into 41 different research subject categories by the three bibliometric databases (Table 2).

Kruskal-Wallis tests indicated significant ( $p=0.001$ ) difference in both CR and Age between the journals. Ranking the journals by median CR and Age allocation into three groups (Table 1) shows the interaction of C at-

Table 3. Descriptive data of publication metrics of top 15 cited articles in *Google Scholar* from 14 biomechanics journals

Metric	Skew ( $\gamma$ )	Max	75%	$M_e$	25%	M	SD	CV
Authors	1.6	12	4	3	2	3.6	1.6	54
Age	0.9	48	21	17	12	17.3	7.4	43
Citations	3.0	6,310	868	360	125	655	853	130
Citation rate	3.0	274	46	22	10	35	40	114

Variables are: Authors=number of authors; Age=2023-year of publication; Citations=total *Google Scholar* citations; and Citation rate=Citations/Age.

Max, Maximum; 75%, 75th percentile;  $M_e$ , median; 25%, 25th percentile; M, mean; SD, standard deviation; CV, coefficient of variation.

traction and Age in biomechanics. High Age group biomechanics journals include both high CR (e.g., *Journal of Biomechanics*) and lower CR (e.g., *Sports Engineering*) journals. There was a significant ( $p=0.027$ ) moderate association ( $r=0.586$ ) between median Age of highly-cited articles of biomechanics journals and their publication history in years.

Disaggregation of journal subject categories in Table 2 by the three CR journal groups shows variation in subject assignments by the bibliometric databases. The number of and variation of subject categories assigned by *Dimensions* and *Scopus* were generally larger for low and average CR groups compared to the high CR group. The high citation rate biomechanics journals generally had the most classifications as health, sports science, and sports medicine research. For example, one hundred percent of the four high CR journals were classified as “Allied Health and Rehabilitation,” “Health Sciences,” and “Sports Science and Exercise” in *Dimensions*. Seventy-five percent or more of high CR journals were classified as “Sport Sciences” by *JCR*. Similarly, *Scopus* classified seventy-five percent or more journals into “Biophysics,” “Orthopedics and Sports Medicine,” and “Sports Science.” “Biomedical Engineering” classified journals were more common in the average (*Dimensions* and *JCR*) and low CR groups (*Scopus*) than in the high CR group.

## 4. DISCUSSION

### 4.1. Biomechanics Journal Citation Metrics

The hypothesized difference in publication metrics within biomechanics journals was supported. There were significant differences in CR and Age of top cited articles published in different biomechanics journals. CR is key input data for numerous journal metrics that are biased proxy estimators of research usage and which must be carefully interpreted (Aksnes et al., 2019; Hicks et al., 2015; Knudson, 2019; Roldan-Valadez et al., 2019). While much of the inquiry and commentary on citation metrics does not clearly define the use of numerous terms (e.g., impact, influence, quality), factor analyses of journal citation metrics clearly align with research usage/popularity or prestige (Bollen et al., 2009; Franceschet, 2010; Leydesdorff, 2009; Leydesdorff et al., 2016; Perera & Wijewickrema, 2018; Walters, 2017; Yan et al., 2011; Zhou et al., 2012). Research on biomechanics and kinesiology journals confirm this two-factor citation metric structure, reporting high associations between usage metrics (e.g., CiteScore, IF, SCImago Journal Rank; Source Normal-

ized Impact per Paper) but with lower associations of these metrics with prestige (Eigenfactor, H Index) metrics (Knudson, 2013; 2015a; Knudson et al., 2023).

Sorting biomechanics journals into three groups by CR (Table 1) shows percentage differences from Average to High and Low groups were between 77 to 108% for CR and 38 to 44% for Age, respectively. These differences have some meaning because they are larger than the 30% variation reported for variability and annual growth of five citation metrics for biomechanics journals (Knudson & Quimby, 2023; Zadpoor & Nikooyan, 2011) or as a standard of meaningful difference in journal metrics from many fields (Amin & Mabe, 2003; Haghdoost et al., 2014; Ogden & Bartley, 2008). This is also confirmatory evidence of meaningful differences in citation rates across research interest areas within biomechanics journals. The current results are consistent with the Knudson and Chow (2008) study of ASB members reporting different perceptions of prestige and quality of biomechanics journals across research areas of interest. It is likely that all journal metrics based on CR create bias in favor or against some research areas within biomechanics because they influence indexing and interpretation based on subject categories with different citation patterns.

Biomechanics journal usage measured by CR also likely interacts with article Age and journal publication history. Inspection of Table 1 shows that a high prestige biomechanics journal like the *Journal of Biomechanics* (Knudson & Chow, 2008) can be influential with high usage (CR) over a long period of time, while other high CR journals (*Gait & Posture*, *Journal of Electromyography and Kinesiology*) may publish highly used research more related to faster and larger health/medical fields of study. Publishing research in a more recently founded and specialized journal will generally be less visible in bibliometric databases that use C and CR to index research, and in turn may lead to fewer citations. The additional C that biomechanics research may attract over time also interacts with well-known differences in speed of decline in citations (e.g., Cited Half-Life) across fields (Haghdoost et al., 2014). There did not appear to be meaningful differences in the number of authors across biomechanics journals. Most highly cited articles had three to four authors, which was consistent with previous research (Knudson, 2012).

### 4.2. Subject Category and Normalization

The biomechanics journals studied were classified into a wide variety (41) of research subject categories that is consistent with a previous study of *JCR* categories for

biomechanics journals (Zadpoor & Nikooyan, 2011). The classification of many categories with similar sets of journals has been reported in biomedical sciences (Rafols & Leydesdorff, 2009; Wang & Waltman, 2016) and is also consistent with bibliometric interpretation of complex or interdisciplinary fields (Katz & Hicks, 1995; Morillo et al., 2001). In addition, the subject categories assigned by databases across the three CR groups were generally consistent with previous research, indicating that health and biomedical journals have higher citation rates than journals classified into engineering, education, or behavioral sciences (Jacso, 2005; Mongeon & Paul-Hus, 2016; Pozsgai et al., 2021; Wu et al., 2012). There is, however, well known inconsistency in assignment of and specific subject categories across databases (Bornmann & Marx, 2015; Haunschild et al., 2022). For example, this study found relatively higher CR in GS for the similar “Sport(s) Science(s) and Exercise” subject that also overlaps with several categories in all databases examined (Allied Health and Rehabilitation, Rehabilitation, and Orthopedics and Sports Medicine).

All these observations support the hypothesis that biomechanics journals may not be easily described with one citation rate on which to base field normalization of journal metrics. The overall median CR of 22 to 26 citations/year (Tables 1, 3) in GS was similar to studies of top cited articles in GS in a study of the journal *Sports Biomechanics* (Knudson, 2020) and seven biomechanics journals within a study of 65 kinesiology journals (Knudson, 2014). However, prestigious (e.g., *Journal of Biomechanics*) and biomedical journals (e.g., *Gait & Posture*; *Clinical Biomechanics*) tend to have CR twice as high. Newer journals (e.g., *International Biomechanics*) and specialized engineering journals (e.g., *Sports Engineering*) may tend to have 77% lower CR. It is important to not take these general percentages literally as likely differences in specific articles’ future citation potential or any other construct (impact, quality, or prestige).

Citation data are not true ratio level measurements due to differences in indexing and errors. Thus, journal metrics calculated with CR, their reporting with false precision, and subsequent efforts to rank journals have received international rebuke (Declaration on Research Assessment [DORA], 2015; Hicks et al., 2015) and are described as inaccurate, an insidious misuse, or a mania (Adler et al., 2008; Amin & Mabe, 2003; Casadevall & Fang, 2014; Knudson et al., 2023). Most articles published in a high CR and consequently high IF journal, however, do not receive high citations and CR because of skewed

citations and the large percentage of uncited articles in journals (Knudson, 2015b; 2023; Seglen, 1992; 1997; Stern, 1990; Zhang et al., 2017). A high CR or IF journal merely has some highly cited articles in a specific time window relative to other journals that should only be used for comparison if they are from a similar field.

It is also important to note that CR and journal metrics vary by the database used and year for their calculation due to different indexing and errors (Franceschini et al., 2015; Meho & Yang, 2007; Moed et al., 2016; Rossner et al., 2008). In biomechanics, for example, Zadpoor and Nikooyan (2011) reported that the two-year IF varied from 1 to 3 across six JCR subject categories between 2002 and 2010. Biomechanics journals classified as “Sport Sciences” had a 2010 IF of about 2, while a more recent study reported eight biomechanics journals related to kinesiology in 2020 had a five-year IF of 2.7 and 27 Sport Science journals had a mean five-year IF of 4.0 (Knudson, 2022a). Persons seeking to field-normalize citation metrics for biomechanics journals, research, or authors should specify specific reference data based on both subject categories and the database used.

### 4.3. Limitations

Several limitations of this study should be considered in interpreting the results. Citation data were limited to the top 15 cited articles in GS. While CR forms the base of numerous journal metrics, it is often unclear how C and CR change by subsequent citable document rate calculations. There are well-known differences in journal metrics that are all based on CR and well-known differences in the size of the same journal metric calculated from different databases, which all influence the current results. The high positive correlation between citations between different databases and several results in the current study consistent with previous research supports the accuracy and potential utility of the current results. Future research is recommended to help clarify research subject categories and differences in CR and journal metrics for biomechanics research.

## 5. CONCLUSIONS

It was concluded that the interdisciplinary and application diversity of the field of biomechanics leads to substantial variation in citation rates in research published in biomechanics journals. This is reflected in variation in research subject categories associated with biomechanics journals by three major bibliometric databases. The lack

of a unique biomechanics category, numerous reference categories, and the meaningful difference (77 to 108%) from low to average and high CR biomechanics journals, make field normalization with subsequent journal metrics difficult. Care must be taken to accurately interpret most citation metrics of biomechanics journals as biased proxies of general usage of research, given a specific database, time frame, and research topic.

## CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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