

## Original Article

# The Most Cited and Influential Publications Relating to Ice Hockey Since 2000 Focus Primarily on Concussion and Traumatic Brain Injuries

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**Purpose:** To determine the most frequently cited articles relating to ice hockey since 2000 and conduct a bibliometric analysis of these publications. **Methods:** The Clarivate Web of Knowledge database was used to gather data and generate a list of publications relating to “ice hockey” on June 20, 2022. Articles were filtered by the total number of citations accrued and were included or excluded on the basis of relevance to ice hockey; no date of publication, language, or journal restrictions. After the 50 most highly cited articles were identified, articles published before the year 2000 were excluded to avoid bias. The information analyzed from each article included author name (first and last), publication year, country of origin, institutional affiliation (of the first and last author), journal name, research design, main research topic, competition level, and the level of evidence. **Results:** Ultimately, 46 studies were included in this analysis. The total number of citations was 8,267 times with an average of 179.7 citations per article. The most cited article was cited 926 times. The articles came from 5 different countries, with the United States and Canada comprising 27 and 13 articles, respectively. All articles were published in English. The *American Journal of Sports Medicine* published the greatest number of articles. The most studied topic was concussion/traumatic brain injury ( $n = 26$ ). Professional hockey was the most studied level of competition ( $n = 15$ ), while college followed ( $n = 13$ ). Three institutions, University of Calgary, Dartmouth School of Medicine, and University of North Carolina at Chapel Hill were responsible for 32.6% of the top articles ( $n = 15$ ). **Conclusion:** The majority of the most cited articles relating to ice hockey are cohort studies, review articles, and epidemiological studies originating from the United States or Canada. The majority of publications included in the analysis focused on concussion and traumatic brain injury prevalence, identification, diagnosis, outcomes, and prevention, as well as the most studied level of competition was professional, but the greatest number of participants arose from the youth and high school level. **Level of Evidence:** Level IV, cross-sectional study

## Introduction

Ice hockey is an international sport and is played in many countries, such as Canada, Russia, Czech Republic, Finland, Switzerland, and Sweden. Although currently not the most popular sport in the United States, ice hockey has experienced substantial growth over the past several years. USA Hockey saw 100,000+ newly registered players across all age groups and skill levels governed by the International Ice Hockey Federation (youth hockey to Olympic level hockey) between 2000 (439,140 players) and 2022 (547,429 players) representing a 24.6% increase in adoption over the past 22 years.<sup>1</sup> As access to skating rinks and winter sport facilities, participation, and television contracts, which broadcast professional hockey continue to grow, more research is needed to ensure the safety of the growing number of participants.<sup>2-4</sup> Continuing ice hockey-related research in fields such as injury

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The authors report the following potential conflicts of interest or sources of funding: A.C. reports consulting fees from Arthrex, Zimmer-Biomet, and Trice Medical. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received August 24, 2022; accepted February 26, 2023.

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<https://doi.org/10.1016/j.asmr.2023.02.014>

prevention, sports medicine, and epidemiological studies will benefit athletes, coaches, and healthcare professionals.<sup>5–7</sup>

With the growing participation of children and young adults in ice hockey has come an increased number of sport-related injuries, as well as new opportunities for research and understanding of preventative strategies and treatments. Research relating to ice hockey is limited but consists of a wide array of topics from injury incidence and preventative technology to the influence of birth date and location on athletic potential.<sup>8–13</sup> With relatively few hockey-related publications compared to other popular sports such as football, basketball, or soccer, it has been difficult to determine the most significant findings in relation to ice hockey injuries. The technique of bibliometric analysis enables a way to quantitatively define research articles with the greatest number of citations as the most impactful in their field.<sup>10,14–17</sup> Bibliometric analysis allows investigators to objectively determine the level of influence a particular collection of articles has had on a field of research and the potential short- and long-term application of such work. Additionally, it allows investigators to determine potential areas that are either over-represented or underrepresented within the scientific literature.<sup>10,14–17</sup> Bibliometric analyses are used in the field of orthopedics and sports medicine for the purpose of medical education but are also used in various other fields such as biotechnology, epidemiology, public health, and preventative medicine.<sup>13,15,18–25</sup>

With the growing number of ice hockey participants of all ages across both the United States and globally has come an increased incidence of injury and a growing interest in injury prevention and sport performance. The purpose of this study was to determine the most frequently cited articles relating to ice hockey since 2000 and conduct a bibliometric analysis of these publications. We hypothesized that the majority of research publications pertaining to ice hockey would be related to concussion and traumatic brain injury (TBI) identification, outcomes, and prevention.

## Methods

Considering the public nature of the data, institutional review board approval was deemed unnecessary. Similar to other studies applying bibliometric analyses of sports medicine literature, the Clarivate Web of Knowledge database was employed to gather both citation and data metrics.<sup>26</sup> The literature search using the Clarivate Web of Knowledge occurred on June 20, 2022. The query was performed by searching all publication titles, abstracts, and keywords for the term “hockey.” No date of publication, language, journal, or country of origin restrictions were placed on this search.

The resulting search list of 5,741 articles was then organized into descending order based upon the total number of citations amassed. Each title and abstract were reviewed to identify its relevance to “hockey” for inclusion in the Top 50 most cited list. For consideration to the list, the publication in question had to include ice hockey players at any competitive level in their research or review. Studies examining multiple sports were contemplated depending on if ice hockey was not only incorporated, but a focal point of the publication. Summary and position statements from conferences, governing bodies, and/or national meetings were excluded if ice hockey was not the primary focus of discussion or if ice hockey athletes were not included as participants in deducing research results. Furthermore, studies that mentioned ice hockey with no orthopedic or medical purpose were excluded due to irrelevance. Articles that pertained to “field hockey” were excluded as well. Additionally, publications with a minor mention of ice hockey in their respective studies were excluded. If a study was not clear or inclusion was questioned, the full text was obtained and reviewed by two authors (J. F. D. and M.L.M) to determine its inclusion or exclusion. If the authors could not come to agreement, the senior author of the study (A. C.) decided on whether it would be excluded.

A total of 153 publications were reviewed to reach the 50 most cited studies that met the inclusion criteria described above. The entire text of the 50 studies was then reviewed to obtain the required information: author name (first and last), publication year, country of origin, institutional affiliation (of the first and last author), journal name, research design (case report, case series, cohort study, descriptive study, epidemiological study, cross sectional study, expert opinion, and review article), main research topic, competition level (club, high school, college, and professional), and the level of evidence. A review article was classified as an investigation that used a systematic approach to reviewing the literature or a meta-analysis of multiple relevant randomized control trials. If an article claimed to review the literature, but neglected to use a clear, systematic methodology of review, it was classified as expert opinion. The level of evidence was determined by a consensus opinion based upon the guidelines published by the Centre for Evidence-Based Medicine.<sup>27</sup> Following data collection, it was found that only 4 articles were published prior to 2000. Therefore, the decision was made to exclude these 4 articles in favor of creating a more up-to-date and less biased selection of highly cited articles.

Furthermore, included articles were analyzed by citation density in addition to the total number of citations generated. Citation density was determined through a calculation of dividing the number of citations by the

**Table 1.** The Top 46 Most Cited Publications Pertaining to Ice Hockey Since 2000

Rank	Article Title	Total Citations	Citation Density
1	Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury <sup>6</sup>	926	51.4
2	Epidemiology of concussions among United States high school athletes in 20 sports <sup>28</sup>	611	61.1
3	Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study <sup>7</sup>	472	27.7
4	The epidemiology of sport-related concussion <sup>29</sup>	394	35.8
5	Neuropsychological test performance prior to and following sports-related mild traumatic brain injury <sup>30</sup>	269	12.8
6	Epidemiology of sports-related concussion in NCAA athletes from 2009-2010 to 2013-2014: incidence, recurrence, and mechanisms <sup>31</sup>	261	20.1
7	Blood biomarkers for brain injury in concussed professional ice hockey players <sup>32</sup>	240	30.0
8	The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players <sup>33</sup>	229	10.1
9	Arthroscopic labral repair and treatment of femoroacetabular impingement in professional hockey players <sup>34</sup>	224	19.1
10	Converging evidence for the under-reporting of concussions in youth ice hockey <sup>35</sup>	200	12.5
11	Subject-specific changes in brain white matter on diffusion tensor imaging after sports-related concussion <sup>36</sup>	196	19.6
12	Incidence of exercise-induced bronchospasm in Olympic winter sport athletes <sup>37</sup>	176	8.0
13	Outcomes after the arthroscopic treatment of femoroacetabular impingement in a mixed group of high-level athletes <sup>38</sup>	175	15.9
14	Mouthguards in sport activities history, physical properties, and injury prevention effectiveness <sup>39</sup>	175	11.7
15	American collegiate men's ice hockey: An analysis of injuries <sup>40</sup>	175	10.3
16	Serum neurofilament light as a biomarker for mild traumatic brain injury in contact sports <sup>41</sup>	173	34.6
17	The incidence of concussion in youth sports: A systematic review and meta-analysis <sup>42</sup>	166	27.7
18	Effect of head impacts on diffusivity measures in a cohort of collegiate contact sport athletes <sup>43</sup>	165	20.6
19	Biomechanics of sport concussion: quest for the elusive injury threshold <sup>44</sup>	164	14.9
20	Electrophysiological evidence for the cumulative effects of concussion <sup>45</sup>	162	7.4
21	Injury rates, risk factors, and mechanisms of injury in minor hockey <sup>46</sup>	154	9.6
22	Risk of injury associated with body checking among youth ice hockey players <sup>47</sup>	152	12.7
23	Prevalence of increased alpha angles as a measure of cam-type femoroacetabular impingement in youth ice hockey players <sup>48</sup>	151	16.8
24	Cognitive effects of one season of head impacts in a cohort of collegiate contact sport athletes <sup>49</sup>	149	14.9
25	Maximum principal strain and strain rate associated with concussion diagnosis correlates with changes in corpus callosum white matter indices <sup>50</sup>	149	14.9
26	Is protective equipment useful in preventing concussion? A systematic review of the literature <sup>8</sup>	142	10.9
27	Survey of sport participation and sport injury in Calgary and area high schools <sup>51</sup>	141	8.8
28	Strength and conditioning practices of National Hockey League strength and conditioning coaches <sup>52</sup>	137	7.6
29	Descriptive epidemiology of collegiate men's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004 <sup>53</sup>	136	9.1
30	Incidence of concussion in contact sports: a systematic review of the evidence <sup>54</sup>	134	7.1
31	Understanding concussion reporting using a model based on the theory of planned behavior <sup>55</sup>	133	16.6
32	Comparison of impact data in hockey, football, and soccer <sup>12</sup>	132	6.0
33	Femoroacetabular impingement in professional ice hockey players: A case series of 5 athletes after open surgical decompression of the hip <sup>56</sup>	129	8.6
34	Collegiate ACL injury rates across 15 sports: national collegiate athletic association injury surveillance system data update (2004-2005 through 2012-2013) <sup>57</sup>	122	20.3
35	Epidemiological considerations of concussions among intercollegiate athletes <sup>11</sup>	120	6.3
36	Concussion increases odds of sustaining a lower extremity musculoskeletal injury after return to play among collegiate athletes <sup>58</sup>	118	19.6
37	A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program <sup>59</sup>	118	10.7
38	Prevalence of cam-type deformity and hip pain in elite ice hockey players before and after the end of growth <sup>60</sup>	114	12.7

(continued)

**Table 1.** Continued

Rank	Article Title	Total Citations	Citation Density
39	Collision type and player anticipation affect head impact severity among youth ice hockey players <sup>61</sup>	110	9.2
40	High prevalence of pelvic and hip magnetic resonance imaging findings in asymptomatic collegiate and professional hockey players <sup>62</sup>	109	9.9
41	NCAA concussion education in ice hockey: an ineffective mandate <sup>63</sup>	109	13.6
42	The effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players <sup>64</sup>	104	5.2
43	Risk factors for groin injuries in hockey <sup>65</sup>	100	4.8
44	Ankle syndesmosis sprains in national hockey league players <sup>66</sup>	95	5.3
45	The avoidability of head and neck injuries in ice hockey: A historical review <sup>67</sup>	95	4.8
46	Hockey Concussion Education Project, Part 1. Susceptibility-weighted imaging study in male and female ice hockey players over a single season <sup>68</sup>	94	11.8

number of years since initial publication. All data collection and summary statistics were completed using Microsoft Excel (Microsoft Corp, Redmond, WA).

## Results

The 46 most cited publications since the year 2000 pertaining to ice hockey are listed in [Table 1](#),<sup>28-68</sup> including their rank, total number of citations, and citation density. The total number of citations per publication ranged from 926 to 94, while 10 articles were cited over 200 times. The 46 included studies were cited a total of 8,267 times, with an average of 179.7 citations per article. The most cited publication obtained 926 citations at the time of the performed search ([Table 1](#)). The second and third most cited publications were 611 and 472, respectively ([Table 1](#)). The median number of citations per article was 151.5.

For included studies, 26 focused on TBI ([Table 2](#)). The second- through fourth-most common area of study were hip pathology/femoroacetabular impingement (FAI) ( $n = 6$ ), injury characteristics ( $n = 5$ ), and adductor muscle/groin strains ( $n = 3$ ), respectively. The most cited ice hockey publications originated from 5 different countries. The majority of the ice hockey articles were published in the United States ( $n = 27$ ), followed by Canada ( $n = 13$ ), Switzerland ( $n = 3$ ), Sweden ( $n = 2$ ), and Norway ( $n = 1$ ). Of the top publications pertaining to ice hockey included in this study, the earliest year of publication was 2000, while the most recent was 2017 ([Fig 1](#)). Between 2000 and 2011, 25 of the top 50 articles were published, while 21 articles have been published in a 6-year span between 2011 and 2017. The years 2011 and 2014 had the most publications ( $n = 5$ ), and 2012 was second ( $n = 4$ ) ([Fig 1](#)). The five most cited articles were published between 2001 and 2012, whereas the top 5 articles ranked by citation density were published between 2004 and 2017. A majority of the top 46 publications pertaining to ice hockey focused on one level of ice hockey competition. Fifteen articles focused on professional ice hockey, followed by college ( $n = 13$ ), club ( $n = 9$ ), and

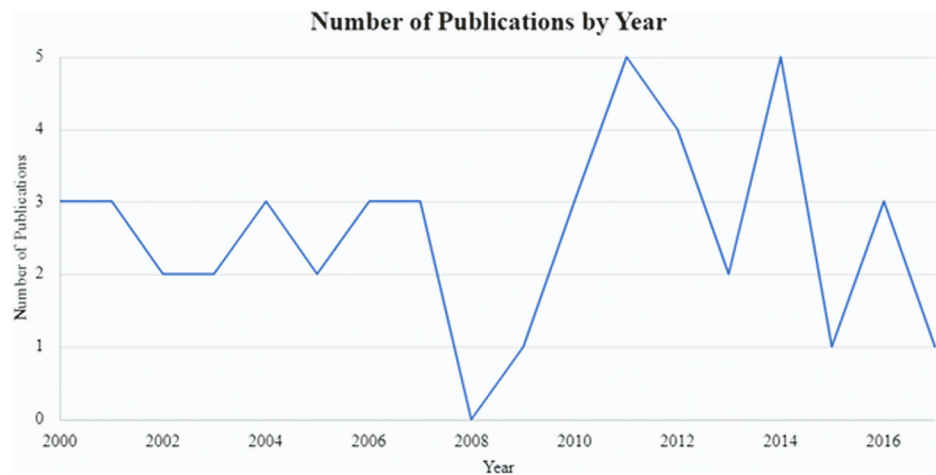
high school ( $n = 4$ ), ([Table 2](#)). No studies consisted of all four levels, while two focused on the three levels of high school, college, and professional athletes.

Of the top 46 most cited articles, the most common level of evidence was Level IV ( $n = 22$ ), while Level I ( $n = 11$ ), Level III ( $n = 7$ ), and Level V ( $n = 5$ ) followed, respectively. Level II research consisted of only 2% of the top publications ( $n = 1$ ). Thirty percent of the top 46 most cited publications were cohort studies ( $n = 15$ ), 24% were review articles ( $n = 12$ ), and 18% were epidemiological studies ( $n = 9$ ) ([Table 2](#)).

**Table 2.** Descriptive Data of the Most Cited Articles Relating to Ice Hockey

Field of Research	Number of Publications
TBI/Concussion	26
Hip pathology/FAI	6
Injury characteristics	5
Adductor muscle/groin strains	3
ACL injury	1
Ankle sprains	1
Exercise induced bronchospasm	1
Injury prevention—mouthguards	1
Jumper's knee	1
Strength and conditioning	1
Level of Competition	Number of Articles
Club	9
High school	4
College	13
Professional	15
High school, college	1
College, professional	1
Club, college, professional	1
High school, college, professional	2
Study Type	Number of Publications
Case report	2
Case series	8
Cohort study	14
Descriptive study	1
Epidemiological study	8
Cross-sectional study	1
Review article	12

ACL, anterior cruciate ligament; FAI, femoroacetabular impingement; TBI, traumatic brain injury.



**Fig 1.** Number of publications per year.

Investigating author impact, 12 authors published more than one of the 46 most cited publications. [Table 3](#) examines author impact through the classification of total number of publications, total number of citations, and average citations per publication, by the first and last author of the top 46 most cited articles ([Table 3](#)). The most active authors within the list were C.A. Emery and T. W. McAllister with 4 first and/or last author publications in total. J. D. Cassidy accumulated the greatest total number of citations ( $n = 1,060$ ) and greatest average citations per publication ( $n = 530$ ) ([Table 3](#)). The three most prolific institutions were the University of Calgary ( $n = 9$ ), Dartmouth College School of Medicine ( $n = 3$ ), and the University of North Carolina at Chapel Hill ( $n = 3$ ), which accounted for 32.6% of all publications in the top 46 list ([Table 4](#)). Investigating journal impact, four out of 21 total journals were responsible for 58.7% of the publications in the top 46 most cited list ([Table 5](#)). The top four journals responsible for publishing the greatest number of articles were *American Journal of Sports Medicine* ( $n = 15$ ), *British Journal of Sports Medicine* ( $n = 4$ ), *Clinical Journal of Sports Medicine* ( $n = 4$ ), and *Neurology* ( $n = 4$ ).

## Discussion

As hypothesized, the majority of the most cited publications relating to ice hockey were related to the field of concussion/TBI identification, outcomes, and prevention. However, a large number of studies relating to commonly experienced injuries, such as hip labral tears, adductor muscle strains, groin strains, ankle sprains, and ACL tears were also present. Moreover, 6 studies focused entirely on the full spectrum of injuries experienced by hockey athletes by characterizing their incidence and prevalence over time. The majority of ice hockey research primarily studied concussion/TBI, and 56.5% of all studies ( $n = 26$ ) identified factors involving the prevalence of head and neck injuries, such as causal factors of concussions, new protective technology, education mandates, and tracking of the recovery process. The influx of literature about head and neck injuries demonstrates the growing concern about athlete safety through all levels of competition. Moreover, 26.1% of the 46 included studies ( $n = 12$ ) illustrated factors involving lower extremity injuries, such as adductor muscle and groin strains, hip labral tears and subsequent hip arthroscopy, ACL tears, ankle sprains, and jumper's knee.

**Table 3.** Descriptive Data of the Authors Included in the Most Cited Articles Relating to Ice Hockey With Two or More Articles Included

Author Name	Number of First Author Publications	Number of Last Author Publications	Total Numbers of Articles Included	Total Number of Citations	Average Citations Per Publication
C. A. Emery	4	0	4	547	136.8
T. W. McAllister	3	1	4	604	151.0
B. W. Benson	2	0	2	260	130.0
M. J. Philippon	2	0	2	375	187.5
E. Kroshus	2	0	2	242	121.0
J. D. Cassidy	2	0	2	1,060	530.0
P. Shahim	2	0	2	413	206.5
J. Agel	2	0	2	258	129.0
T. F. Tyler	2	0	2	333	111.5
J. P. Mihalik	1	1	2	274	137.0
K. M. Guskiewicz	1	1	2	274	137.0



**Table 4.** Institutions With Two or More Affiliated First and/or Last Authors of the Most Cited Articles Relating to Ice Hockey

Institution of First or Last Author	Number of Publications
University of Calgary	7
Dartmouth College School of Medicine	3
University of North Carolina at Chapel Hill	3
University of Alberta	2
Steadman Phillips Research Institution	2
Norwegian School of Sports Science	2
Simon Fraser University	2
Sahlgrens University Hospital, Clinical Neurochemistry Lab,	2
Lenox Hill Hospital, Department of Orthopedics	2
Harvard University, Department of Public Health	2
Washington University in St. Louis, School of Medicine	2

The most cited publication in the top 46 list ( $n = 926$ ) was a review article about mild traumatic brain injuries among club, college, and professional hockey players. Concussions are a relatively common injury sustained by hockey players of all levels.<sup>69–71</sup> Moreover, concussion research, prevention, symptomatology, and treatment have been a growing field within sports medicine and neuroscience.<sup>16,24,72</sup> Although boys high school football has the highest incidence of 10.4 concussions per 10,000 athlete exposures, boys ice hockey is second among male athletics with 7.7 concussions per 10,000 athlete exposures.<sup>73</sup> Across all age and skill levels of competitive ice hockey, concussions account for up to 14% of all hockey injuries and 30% of all head injuries.<sup>74</sup> Further, these numbers fail to illustrate the underreporting of concussions in competition. A recent study by Wallace et al. showed that high school athletes in many sports, including ice hockey, football, soccer, basketball, and volleyball underreported concussions and concussion-like symptoms by up to 55%, even when they were educated on the presenting signs and had access to a healthcare professional like an athletic trainer at their school.<sup>75</sup> Therefore, while many of the articles in the present analysis focused on concussion and TBI identification outcomes and prevention, additional research on strategies that could be used to promote more honest and open reporting of concussions among athletes at all levels may be warranted.

There are also many factors that influence the total number of citations each article generates. Even though 6 different countries were represented in the bibliometric analysis, all studies were published in English and the majority came from the United States and Canada. This was not surprising as the United States and Canada are ranked first and second as the most registered ice hockey players in the world, respectively.<sup>1,3,76,77</sup> However, more representation from nations where ice hockey reigns as the most popular sport was also expected. This finding may suggest that authors publishing outside of these two nations are at a

disadvantage with a lack of research participants or funding for hockey-related medical research. Furthermore, the time of publication influenced the total number of citations an article received. While possibly seeming counterintuitive, this was not entirely unexpected as many journals require updated citations which leaves articles published many years ago less and less likely to accumulate high number of citations. Moreover, the older articles in this analysis may have also suffered from a phenomenon known as “obliteration by incorporation,” where foundational knowledge no longer requires citation and is accepted as common knowledge.<sup>19</sup> This suggests as hockey continues to grow in both participation and fandom, more research is being done on prevalence and prevention of common injuries physicians will encounter.

Additionally, the present analysis saw a large spike in highly cited research between 2011 and 2017, with 52.2% of included articles being published in this 7-year time frame. Moreover, 47.3% of the total citations accumulated by the most cited works could be attributed to articles published during this time. Since 2017, there has been a relative absence of highly cited articles; however, this is likely secondary to articles published over the past 5 to 6 years having too little time to accumulate enough citations to be included in this analysis. This aligns with recent studies on the rapid growth of ice hockey scholar publications found on academic research databases from 2000 to 2019.<sup>78</sup> As an increase in concussion studies continue to arise from sports such as football and hockey, both researchers and physicians alike desire to prevent the dramatic increase of head trauma in competitive ice hockey.<sup>2,16</sup> As more quantifiable data illustrate the impact of repeated hits to the head, there are more calls to change the fundamental ways the game is played, so that players are protected.<sup>2</sup> The 26 publications on the list pertaining to concussion/TBI may be attributed to the global awareness of head trauma in high-contact athletics.

The present analysis revealed that several researchers and institutions were well represented, as authors or places of research for the most cited articles relating to ice hockey over the past 22 years. Namely, C. A. Emery, T. W. McAllister, and J. D. Cassidy all published multiple articles and generated an impressive number of

**Table 5.** Publishing Journals of the Most Cited Articles Relating to Ice Hockey With Two or More Articles

Journal of Origin	Number of Publications
<i>American Journal of Sports Medicine</i>	15
<i>British Journal of Sports Medicine</i>	4
<i>Clinical Journal of Sports Medicine</i>	4
<i>Neurology</i>	4
<i>JAMA: Journal of American Medical Association</i>	2
<i>Brain Injury</i>	2
<i>Medicine and Science in Sports and Exercise</i>	2

citations from their works. Emery's works were most notable for analysis and characterization of the most common injuries experienced by ice hockey athletes.<sup>46,47,51,65</sup> Most notably, the line of research produced by Emery emphasizes that to be a successful, highly cited researcher in this field, you are not required to focus all study on concussion or TBI topics. Analysis of more routine, musculoskeletal mechanisms of injury are also highly important in providing the foundation for more targeted research that is injury or mechanism specific. On the other hand, researchers McAllister and Cassidy built their highly cited research portfolio on the incidence, characterization of risk factors, diagnosis, outcomes, and prevention of concussion and TBI in contact sport athletes.<sup>6,43,49,50</sup> As previously mentioned, concussion-related research is increasingly important for contact sports, such as ice hockey as the long-term sequelae associated with repeated blows to the head and neck have become better understood. These works have provided a valuable foundation for which future research pertaining to ice hockey athletes of all levels can be built on. Additionally, a familiarity of the most influential works in this field and who conducted them can inform future research collaborations and ideas as this field continues to move forward.

The majority of the most cited articles were published in only 4 journals, which is representative of the major influence and reputation these journals occupy within the field of sports medicine and orthopedics. Specifically, the *American Journal of Sports Medicine* is the most cited and, therefore, influential journal in the field of sports medicine.<sup>79</sup> Further, all journals responsible for more than 1 publication specialized in a specific field of medical research. Additionally, despite most studies being published in high-impact academic journals, there was a deficit of articles with high-quality evidence. Only 23.9% (n = 11) articles were Level I evidence, while 58.7% were Level IV or V. This finding represents an opportunity for future researchers to prioritize Level I and II studies to fill this gap in the literature and further strengthen this field.

### Limitations

This study is not without limitations. A limitation of the bibliometric analysis included the selection criteria for the identification of the most cited publications relating to ice hockey. Although the selection criteria for inclusion in the list was well defined, the decision to exclude or include publications contained some component of subjectivity. This limitation was addressed by including multiple authors to determine whether a publication should be included or not. Further, publications were chosen for the total citations amassed since publication. The number of citations generated can be influenced by numerous factors, such

as language of origin, journal publication, and time since publication. The number of citations is a crucial factor but is not the sole determinant of overall influence. This could have resulted in articles with a tremendous impact in their field to be overlooked because of the factors listed above. Additionally, journals often require new works to use updated citations, which naturally excluded older works from accumulating citations as time goes on. More recent publications may also not have had the ability to gain enough citations to be deemed distinguished in ice hockey research. This could have potentially excluded highly important and influential articles published over the past few years. Finally, the Clarivate Web of Knowledge database was used as the only database in this bibliometric analysis. Although this database is prominent and widely used among similar analyses, other databases may yield different results through search criteria, citations amassed, and categorization of articles.<sup>10,13–18</sup>

### Conclusion

The majority of the most cited articles relating to ice hockey are cohort studies, review articles, and epidemiological studies originating from the United States or Canada. The majority of publications included in the analysis focused on concussion and traumatic brain injury prevalence, identification, diagnosis, outcomes, and prevention, as well the most studied level of competition was professional, but the greatest number of participants arose from the youth and high school level.

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