

The 100 Most Cited Articles on Healthcare Simulation

A Bibliometric Review

Chloe Walsh, MSc;

Sinéad Lydon, PhD;

Dara Byrne, MMed Ed;

Caoimhe Madden, MSc;

Susan Fox, PhD;

Paul O'Connor, PhD

Summary Statement: This article provides an overview and synthesis of the 100 most cited healthcare simulation publications to provide insight into the articles that have shaped current knowledge and practice. Searches of the Scopus and Web of Science databases were conducted in July 2017. Most articles were concerned with medical education and training (86%) and were most often published in surgical journals (33%). Manikins (20%), standardized patients (16%), inanimate part-task trainers (16%), fully simulated environments (17%), and virtual reality part-task trainers (14%) were the most commonly featured types of simulators. Healthcare simulation research has matured and grown during the preceding decades. There has been a move away from research questions focused on “does simulation work?” to an assessment of the conditions under which simulation is most effective. It is hoped that providing an overview of highly cited works will help identify topics for further research.

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Because the use of simulation has become more established within the delivery of healthcare education and training, the healthcare simulation research literature has experienced corresponding growth.^{1,2} A trend in medical and healthcare literature has been to conduct citation analyses to identify the most cited works in a particular field.^{3,4} To our knowledge, no such works have been conducted pertaining to the use of simulation in healthcare education and research. As such, with the increase in the use of simulation in healthcare education and the growth of healthcare simulation research for the past three to four decades, it seems that this is an appropriate time to take stock and to examine the nature of those articles that have been cited the most within the field of healthcare simulation.

The number of citations received is often used as a measure of the impact an individual article, author, journal, or institution has had on a field of research, with a basic assumption that high numbers of citations are indicative of high levels of impact.^{5,6} Therefore, identifying the most cited articles can

be useful in identifying “classic” works in a field and highlighting areas for future research.⁶ Although a frequently used approach,⁷ there are a number of limitations to the use of citation analysis, which must be taken into account, such as the potential for a risk of bias as a result of older publications having had longer time to accumulate citations, or the way in which the citation practices of individuals can affect citation rates.⁸ Nevertheless, when appropriately applied, interpreted, and analyzed, citation analysis can be a useful tool to provide some indication of which authors, articles, and topics are influencing or motivating research in a field.^{9,10}

This article aims to identify the 100 most highly cited articles in healthcare simulation education and research and to report on the characteristics of these publications. The hope is that this analysis will (1) provide insight into the history and development of the field of simulation in healthcare education and research and (2) provide an overview of research in the area and insight into the articles that have helped shape current knowledge and practice.

METHODS

Study Design

This article describes a citation analysis of journal articles in the field of healthcare simulation education and research. Although somewhat arbitrary, the top 100 articles were chosen as this is consistent with other bibliometric reviews in the healthcare fields^{3,4,11,12} and offer the reader more information as opposed to reporting just the top 10 or the top 50 articles in a field.

Search Strategy and Study Selection

Searches were conducted in the Scopus and the Web of Science databases (Clarivate Analytics, Philadelphia, PA) in July

From the School of Medicine (C.W., S.L., D.B., C.M., S.F., P.O.), National University of Ireland Galway; Galway University Hospital Galway (D.B.); and The Irish Centre for Applied Patient Safety and Simulation (C.W., S.L., D.B., C.M., S.F., P.O.), Galway, Ireland. Reprints: Paul O'Connor, PhD, Department of General Practice, 1 Distillery Rd, National University of Ireland, Galway, Ireland H91 TK33 (e-mail: paul.oconnor@nuigalway.ie).

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Ethical approval was not sought for this article, as we were not collecting data from any individuals but reviewing existing research studies.

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2017. Publications pertaining to “simulation-based education” or “simulation-based research” and “health care professionals” were identified. No time limits were imposed on the searches, although searches were limited to the English language because of resource limitations (see table, Supplemental Digital Content 1, <http://links.lww.com/SIH/A357>, for detailed search strategy). In both databases, the retrieved articles were sorted using the sorting option “times cited – highest to lowest.” The outputs from both databases were presented in a descending order, with the higher cited articles at the top of the list, and were exported to two separate Excel spreadsheets for further analysis. Two reviewers (C.W. and S.F.) independently applied the inclusion and exclusion criteria to each article within the two lists. The full texts were then screened, independently, until each reviewer had developed a list of 100 eligible articles. Cohen's κ indicated high interrater reliability ($\kappa = 0.83$, sensitivity = 0.94, specificity = 0.82). To resolve any disagreements, the research team would review the article(s) in question, in detail, together, and discuss the issues at length until consensus was reached.

Eligibility Criteria

Studies were eligible for inclusion if they are the following:

- described the employment of simulation using virtual reality (VR) simulators, standardized or simulated patients (SPs), inanimate part-task trainers, high-fidelity and static manikins, live animals, inert animal products, cadavers, and role-plays;
- included healthcare personnel (eg, doctors, nurses, health profession students, allied healthcare professionals);
- were focused on the teaching and/or assessment of clinical or procedural skills; and
- were published in an English language, peer-reviewed journal.

Studies were ineligible for inclusion if they are the following:

- described simulation-based education with individuals other than healthcare professionals or health profession students;
- had a focus on computational simulation or mathematical modeling;
- did not have healthcare simulation education or research as a key focus; or
- featured written clinical vignettes alone. Because of the lack of interactive components, for the purpose of this review, these do not constitute simulation technology.¹³

Data Extraction

For both databases, data were extracted independently by two reviewers. For Scopus, the data were extracted by C.W. and C.M., and for Web of Science, the data were extracted by C.W. and S.F. Information was extracted on the following variables: (1) author and publication year; (2) number of citations; (3) country of publication (based on the first author's affiliation at the time of publication); (4) participants/population of focus; (5) type of simulator used; (6) type of targeted skill (ie, technical or nontechnical); (7) subject/discipline; and (8) article type (eg, intervention, systematic review). High percentage agreement between the raters was found for both databases (Scopus percentage agreement = 94%; Web of Science percentage agreement = 96%) (see table, Supplemental Digital Content 2, <http://links.lww.com/SIH/A358>, for data extraction table).

Top 100 List Citations

The list of the top 100 cited articles was compiled and ranked according to the outputs from the Scopus database search. Scopus was selected as the primary database because

it covers more journals (approximately 21,500 journals)¹⁴ compared with Web of Science (approximately 18,200 journals).¹⁵ Furthermore, a number of key simulation journals such as *Simulation in Healthcare*, *Journal of Clinical Simulation in Nursing*, and *British Medical Journal of Simulation and Technology Enhanced Learning* are indexed within Scopus, but not Web of Science. To obtain the citation counts from Google Scholar and Web of Science, each article from the Scopus list was individually searched for in these other databases and reported alongside the Scopus outputs (see table, Supplemental Digital Content 3, for list of citations for all three databases). Publications with the same number of citations were ranked at the same position.

Self-citations

Using the “exclude self-citations” option in Scopus, the percentage of self-citations within the list of 100 most highly cited articles derived from Scopus was calculated.

Statistical Analysis

The Pearson correlation coefficient (r) was calculated to determine whether the number of years since publication was correlated with total number of citations among the included articles.

Publication Trends

Additional searches using the terms “simulation in healthcare” and “simulation-based medical education” were conducted within Scopus. These searches and the resultant

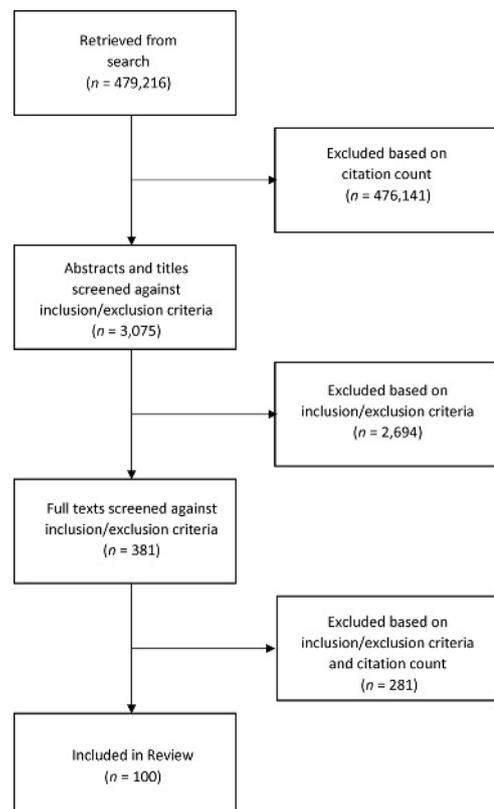


FIGURE 1. The PRISMA flowchart of study selection. PRISMA flowchart of the process of how included studies were selected with reported numbers of retrieved records at each stage.

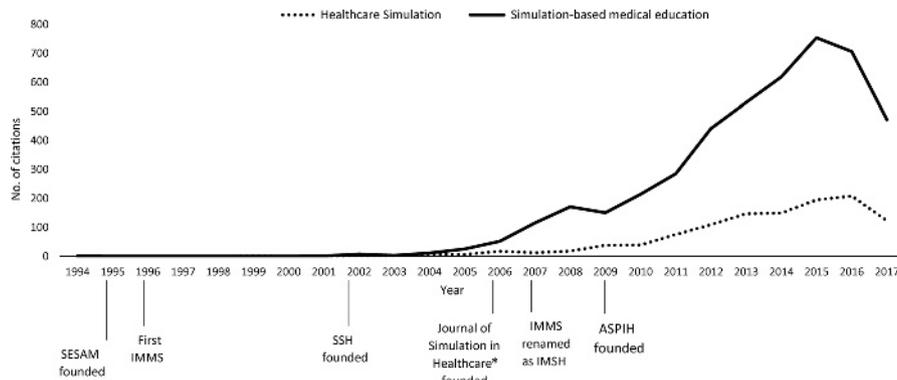


FIGURE 2. Publications by year in Scopus under the terms “healthcare simulation” and “simulation-based medical education” from 1994 to 2017. Important events in healthcare simulation history are also presented. SESAM indicates Society in Europe for Simulation Applied to Medical Education; IMMS, International Meeting on Medical Simulation; SSH, Society for Simulation in Healthcare; IMSH, International Meeting for Simulation in Healthcare; ASPIH, Association for Simulated Practice in Healthcare. *Later in 2006, this was renamed as the *Journal of the Society for Simulation in Healthcare*.

data provide a broad overview of the publication trends of articles using these terms.

RESULTS

Study Selection

Because of the differences in the outputs from each database, it was impossible to compile a single list of the top cited articles. The flow diagram for the Scopus screening process is provided in Figure 1. The initial search in Scopus returned 479,216 results, of which the titles and abstracts of the 3075 highest cited texts were screened against the eligibility criteria. The full texts of 381 articles were then examined until the 100 most cited articles remained. A table of the full list of the top 100 publications according to Scopus, along with the number of citations those articles received in Web of Science and Google Scholar, are provided in Supplemental Digital Content 3 (see table, Supplemental Digital Content 3, <http://links.lww.com/SIH/A359>, for a list of publications with citations). A full list of the 100 most cited publications returned from the Web of Science search is also provided (see table, Supplemental Digital Content 4, Web of Science list, <http://links.lww.com/SIH/A360>).

Self-citations

Self-citations were found to comprise 5.7% of the total number of citations in the Scopus top 100 list.

Publication Trends

Figure 2 provides an overview of publication trends within Scopus under the search terms “healthcare simulation” and “simulation-based medical education.” An increase in articles using these terms was observed from 1994 onward. A substantial growth is evident from 2005 onward. Figure 2 also indicates key events that have occurred in healthcare simulation in terms of establishing it as a discipline (eg, founding of international societies and discipline specific journals). Figure 3 shows the publication trends for the articles in the included list between 1988 and 2011. A general increase in the number of publications was observed, which peaked in 2004 and 2006.

Study Characteristics

The characteristics of the top cited articles retrieved from Scopus are shown in Table 1. The most commonly cited articles were published between 1988 and 2011 with a citation range from 1411 to 186 (mean [SD] = 361.55 [237.27]). No significant correlation was found between years since publication and number of citations ($P = 0.48$) (see figure, Supplemental Digital Content 5, <http://links.lww.com/SIH/A361>, which illustrates the Pearson coefficient).

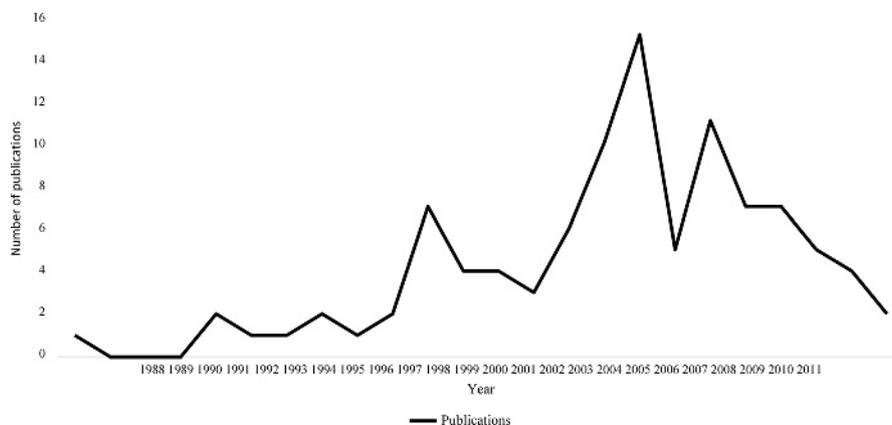


FIGURE 3. Publication trends for the articles included in this review.

TABLE 1. Study Characteristics of Top 100 Published Articles

Study characteristics	Frequency (%)	Mean (No. Citations)	SD (No. Citations)	Range (No. Citations)
1. Country of origin				
United States	45	412.4	275.8	1141–186
United Kingdom	27	289	97.3	536–188
Canada	16	388.8	246.2	1084–202
Denmark	4	323.5	258.4	711–189
Australia	3	258.7	6.7	263–251
The Netherlands	2	217	35.5	240–194
Sweden	2	242.5	41.7	272–213
Israel	1	—	—	398
2. Focus of article/type of study*				
Review (nonsystematic)	35	378	201.1	1201–186
Intervention	28	321.5	250.9	1411–194
Tool evaluation/development	18	359.6	236.1	1084–199
Systematic review/meta-analysis	7	447.3	404.5	1342–188
Observational	6	289.8	87	443–220
Performance assessment	5	183	56.3	348–189
User evaluations	2	233	60.8	276–190
Curriculum development	1	—	—	189
Editorial	1	—	—	192
Invited address	1	—	—	1066
3. Subject/discipline*				
Medical education/training	86	371.9	240.7	1141–186
Surgery	45	352.8	239.1	1411–186
Laparoscopy/MIS	23	352	266.9	1411–188
Generic	21	352	217.6	1084–106
Endoscopy	1	—	—	287
Crisis/crew resource management	15	277.1	86.6	480–192
Doctor-patient communication	11	304.5	126.2	536–194
Anesthesiology	9	304.4	101.4	480–192
Assessing clinical competence/quality of care	6	585.8	344.4	1201–211
Nursing education/training	5	263.2	103.9	445–190
Oncology	5	302.2	140.7	536–197
Primary care	4	430.5	192.4	656–211
Team training	4	242.6	39.5	291–100
Critical/emergency care	3	235.3	29.1	256–202
Obstetrics/gynecology/midwifery	2	226.5	44.6	258–295
Healthcare in general	1	—	—	562
Health professions education and training	1	—	—	461
4. Targeted skill				
Technical skills	41	358.8	247.4	1411–188
Both	34	422.2	280	1342–186
Nontechnical skills	25	232.9	232	1342–194
5. Type of simulator*				
Various/nonspecified	40	414.4	288.1	1342–186
Manikins	20	274.5	76.9	480–190
Standardized/SP	16	331.7	144.1	656–197
Inanimate part-task trainers/box trainers/bench models	16	320.4	129.1	622–203
Full simulated environment	17	264.5	73.7	480–190
VR (part-task trainers)	14	367.4	331.9	1411–188
Live animals/animal parts	4	286.2	75.1	389–213
Role-play	3	197	4.2	200–194
Cadaver	1	—	—	338
Computerized clinical vignette	1	—	—	350

*Many articles fit into more than 1 category and so column does not add to 100%.

The 100 Most Cited Articles

Country of Publication

As can be seen within panel 1 of Table 1, almost half of the studies within the 100 most cited articles were published in the United States (45%),^{1,13,16–58} with the United Kingdom as the next highest contributor (27%),^{59–85} followed by Canada (16%).^{86–101}

Type of Study

The distribution of the number of publications by type of study is shown in panel 2 of Table 1. Nonsystematic reviews (35%)^{1,13,20,23,24,28,29,31,32,35,37–39,42,44,48,50,51,58,60,62,64–66,68,69,73,80,82,83,85,87,93,102,103} were the most common type of study within the 100 most cited articles, followed by interventions (28%)^{18,25,26,30,36,41,43,45,49,53–55,63,75–78,81,90,92,95,96,104–108} and studies focusing on tool evaluation/development (18%).^{22,34,52,59,61,70,74,76,79,86,88,89,91,94,98–100,109} Systematic reviews/meta-analyses (7%),^{19,27,33,84,110–112} observational studies (6%),^{16,46,47,71,90,97} articles describing performance assessments (5%),^{17,67,99,109,113} user evaluations (2%),^{40,57} and curriculum development studies (1%)¹¹³ were less commonly cited. The focus of a small number of articles (5%)^{74,76,99,109,113} was deemed to fall across two or more categories.

Subject/Discipline

The breakdown by subject/discipline is presented in panel 3 of Table 1. Many studies are related to several subjects or disciplines, and this is reflected in the results. For example, crisis resource management was often studied within anesthesiology^{17,30,35,40,49,54,56,59,73,106} or surgical teams.^{30,53,95} Most studies (86%)^{1,13,16,18–21,23–26,30–33,35–50,53–55,58–60,62–66,68–73,75–77,79–112} had a key focus of medical education/training, defined as a “discipline covering the education, and the practice of, skills by students enrolled in medical schools/colleges to become doctors; residency training, continuing medical education; and specializing

TABLE 2. Journals That Have Published the Highly Cited Articles in the List Retrieved From Scopus

Journal	Frequency (%)	Mean (No. Citations)	SD (No. Citations)	Range (No. Citations)
<i>American Journal of Surgery</i>	9	321.9	136	622–199
<i>Annals of Surgery</i>	8	438.5	408.2	1141–189
<i>Medical Education</i>	7	304.6	100.1	507–196
<i>Academic Medicine</i>	7	414.9	300.7	1066–202
<i>JAMA</i>	6	555.2	358.3	1201–220
<i>British Journal of Surgery</i>	5	488.6	397.1	1084–188
<i>Surgical Endoscopy and Other Interventional Techniques</i>	5	226.4	34.9	287–203
<i>Quality and Safety in Healthcare</i>	4	311	168.8	562–202
<i>Archives of Internal Medicine</i>	3	352	141.1	505–227
<i>British Journal of Anesthesia</i>	3	319.3	139.3	480–238
<i>British Medical Journal (BMJ)</i>	3	322	116.2	423–195
<i>Journal of the American College of Surgeons</i>	3	334.7	122.4	476–263
<i>The Lancet</i>	3	441.3	115.3	536–313
<i>New England Journal of Medicine</i>	3	581	183	740–381
<i>Anesthesiology</i>	3	272	78.1	348–192
<i>Annals of Internal Medicine</i>	2	272	110.3	350–194
<i>Critical Care Medicine</i>	2	243.5	6.4	248–239
<i>Journal of Advanced Nursing</i>	2	232.5	26.2	251–214
<i>Journal of Nursing Education</i>	2	203	18.4	216–190
<i>Simulation in Healthcare</i>	2	332	111.7	411–253
Others	18	340.1	263.1	1342–186

TABLE 3. The 10 Highest Cited Publications in Healthcare Simulation as Listed in Scopus

Rank	Author and Year	Scopus Citations	Description
1	Seymour et al, 2002 ¹⁸	1141	A prospective randomized trial investigating whether VR training transfers technical skills to the operating room to reduce error risk in laparoscopic surgery.
2	Issenberg et al, 2005 ¹⁹	1342	A BEME systematic review of 109 articles on the features and uses of high-fidelity medical simulations that lead to effective learning.
3	Epstein and Hundert, 2002 ²⁰	1201	A nonsystematic review in which the authors discuss the assessment of clinical competence, including the use of standardized patients and OSCE examinations in the assessment of physical examination and technical and communication skills.
4	Martin et al, 1997 ⁸⁶	1084	Preliminary study to (1) compare the reliability of 3 scoring systems, (2) compare live animals and bench models, and (3) assess the construct validity of the OSATS. Surgical residents' performance was graded using checklists, global rating forms, and pass/fail judgments.
5	Ericsson 2004 ²¹	1066	An invited address in which Ericsson discusses the use of simulation for deliberate practice in medical education/training.
6	Reznick and McRae, 2006 ⁸⁷	740	A nonsystematic review in which the authors discuss the use of simulation in surgical training.
7	Grantcharov et al, 2004 ¹⁰⁴	711	A randomized controlled trial. Surgical trainees were randomized either to receive VR training on the MIST-VR or to receive no training.
8	Peabody et al, 2000 ²²	656	A prospective trial compared the following 3 methods for measuring quality of care: (1) structured reports by standardized patients, (2) abstraction of medical records, and (3) physicians' responses to clinical vignettes.
9	Epstein, 2007 ²³	622	A nonsystematic review in which Epstein also discusses the various methods of assessment in medical education, including clinical simulations.
9	Reznick et al, 1997 ⁸⁸	622	An assessment of the reliability and construct validity of the OSATS. 48 general surgery residents completed a 2 hour 8 station OSATS and were assessed at each via 2 methods of scoring.

OSATS indicates Objective Structured Assessment of Technical Skills; BEME, Best Evidence Medical Education; OSCE, Objective Structured Clinical Examination.

postgraduate training.^{114(p.1148)} Surgery accounted for 45% of articles.^{18,26,28,30,39,41,53,58,61,62,66-70,74-77,79,84,86-96,98,99,101-105,107-109,111-113} This was followed by crisis/crew resource management (15%)^{17,30,35,37,40,43,49,53,54,56,59,73,80,95,106} doctor-patient communication (11%),^{25,36,45,48,55,63,72,81,82,85,97} and anesthesiology (9%).^{17,30,35,40,54,56,59,73,106}

Targeted Skills

It can be seen from panel 4 of Table 1 that of the 100 most cited articles, the majority (41%)^{16,18,26,28,39-41,46,47,61-63,67,69,70,75-77,84,86-96,98,99,101,103-105,107-109,111-113} were focused primarily on technical skills (ie, the knowledge, skills, and ability to accomplish a specific medical task, such as suturing or performing a physical examination.^{115(p.38)} Articles focused specifically on nontechnical skills (eg, communication, decision-making, history taking skills) were less common (25%).^{25,30,36,37,43-45,48,50,51,53-55,59,63,66,72-74,79-82,85,100} Finally, 34%^{1,13,17,19-24,27,29,31-35,38,42,49,52,56-58,60,64,65,68,71,78,83,97,102,106,110} of articles focused on both technical and nontechnical skills. For example, in full-scale simulations, the focus was often directed at training/assessing communication skills as well as technical ability.⁷⁸

Type of Simulator

Panel 5 of Table 1 shows the frequency of the different types of simulators used. Most articles (40%)^{1,13,19-21,23,24,27,29,32-34,38,41,44,50,56,58,62,64-66,68,74-78,80,83,86,87,92,93,95,102,103,107,111,112} discussed or used multiple types of simulators. For example, review articles sometimes provided an overview of or comparisons between various tools useful for a specific discipline (eg, various tools available for training and assessment in laparoscopic surgery⁶⁹); the history and development of the field (eg, the development of simulation for medical education⁶⁴); and future directions.¹³

Manikins were the next most commonly used type of simulator (20%).^{16,17,30,35,37,40,43,46,47,49,51,54,57,59,71,73,78,79,106,110} They were used to teach a variety of technical and nontechnical skills within medical education and training (15% of all articles)

^{16,30,35,37,40,43,46,47,49,54,59,71,73,79,106}; crisis/crew resource management (11% of all articles)^{17,30,35,37,40,43,49,54,59,73,106}; anesthesiology (7% of all articles)^{17,35,40,54,59,73,106}; nursing (4% of all articles)^{51,57,78,110}; emergency medicine (3% of all articles)^{43,46,47}; team training (2% of all articles)^{37,43}; surgery (2% of all articles)^{30,79}; and obstetrics and gynecology (1% of all articles).⁷¹

Simulated patients were featured in 16%^{22,25,34,36,42,45,48,52,60,63,72,81,82,85,97,100} of articles in the teaching/assessment of non-technical skills across a number of subject areas/disciplines, eg, medical education (13% of all articles),^{25,36,42,45,48,60,63,72,81,82,85,97,100} doctor-patient communication (10% of all articles),^{25,36,45,48,63,72,81,82,85,97} oncology (5% of all articles),^{36,63,72,81,82} and primary care (4% of all articles).^{22,25,34,52}

Inanimate part-task trainers are also featured in 16% of articles,^{26,41,70,75,76,88-92,94-96,98,99,101} all of which were surgical articles, in particular laparoscopic surgery (10% of all articles).^{26,41,75,76,89,90,94,96,99,101}

Fully simulated environments were featured in 17% of articles.^{17,30,35,37,40,43,49-51,54,57,59,73,78,79,106,110} These full-scale simulations were often used in relation to crisis/crew resource management training (11% of all articles)^{17,30,35,37,40,43,49,54,59,73,106} and in nursing (4% of all articles).^{51,57,78,110}

Virtual reality part-task trainers were featured in 14% of articles^{18,28,39,67,69,75,76,84,104,105,107-109,113} and were used almost entirely in relation to laparoscopic (12% of all articles)^{18,67,69,75,76,84,104,105,107-109,113} and minimally invasive surgery (MIS) (1% of all articles).²⁸ One study compared computerized clinical vignettes with SPs for the assessment of clinical competence.³⁴

Live animals/inert animal products (4%),^{41,61,95,107} role-play (3%),^{53,55,82} and cadavers (1%)⁹² were less commonly featured as a key mode of simulation.

Journal

The journals, which have published the top cited articles, are presented in Table 2. Surgical journals have contributed the

most articles (33%),^{18,26,28,39,41,53,58,66,69,70,75,77,79,84,86,88–90,92–96,99,101,103–105,107,109,111–113} followed by general medical journals (22%)^{20,22–25,27,32,34,36,38,45,46,52,55,60,62,63,67,85,87,97,108} and medical education journals (15%).^{1,19,21,33,42,48,64,65,68,74,83,91,98,100,102} Simulation-specific journals have contributed 3% of the top cited articles.^{31,35,44} Any journals, which have contributed less than two articles to the top cited list, are grouped under the category of “other” in Table 2.

The 10 Most Cited Articles

Table 3 presents a summary of the ten most highly cited articles. These articles include the following: two controlled interventions in which VR task trainers were used to improve laparoscopic surgery skills^{18,104}; a systematic review investigating the features and using high-fidelity simulation associated with effective learning¹⁹; and three nonsystematic reviews, which discussed the use of various simulators in the assessment and training of both technical and nontechnical skills.^{20,23,87} Two studies evaluated the use of part-task trainers⁸⁸ or a combination of part-task trainers and live animals⁸⁶ to assess/train technical skills, whereas one study²² compared the use of SPs with written clinical vignettes in the assessment of the quality of care provided by physicians. Finally, one of the top cited articles was an invited address²¹ in which the use of simulation is discussed in relation to deliberate practice in medical education/training.

DISCUSSION

The aims of this study were to identify the 100 most cited articles in simulation in healthcare education and research and to describe the characteristics of these articles. The top cited articles, according to the Scopus database, were published between 1988 and 2011 and came mainly from the United States (45%). Nonsystematic reviews (35%) and interventions (28%) were the most common type of publication and 40% of the articles used/discussed multiple simulators. Most articles focused on the education and/or training of medical professionals (86%) across domains, but surgery was the most common specialty (45%). Furthermore, technical skills (41%) were more often featured than nontechnical skills (25%), and surgery-specific journals (33%) have contributed the largest number of highly cited articles in the current list. The increasing trend of publications relating to healthcare simulation education and research suggests that it has become a widespread and accepted methodology in the education of healthcare professionals.

The specialty of surgery dominated the top 100 most cited articles, more specifically, laparoscopic surgery. It is well recognized that basic laparoscopic skills are well suited to practice on a simulator.⁵⁸ This finding may also be partly attributable to the fact that the rise in simulation has occurred concurrently with the growth of MIS. Assessing the acquisition of laparoscopic skills fits well within the “scientific method” with clear, measurable performance metrics (eg, time, instrument motion).

The high representation of interventions (28%) in the 100 most cited articles may suggest that there has been a “burden of proof” to demonstrate that healthcare simulation is an effective training and education tool. In the past decade, however, systematic reviews and meta-analyses have been conducted and are attaining high citation counts, despite only

being published in recent years.^{19,27,33,84,110–112} Such studies are useful for advancing research, directing practice, and facilitating decision-making, so the increasing appearance of these types of studies is unsurprising and provides further evidence of the maturation of the field.^{116–118}

A general increase in the amount of publications per year was observed for the period covered (1988–2011) by this review, which reflects the growth of the field. Similar findings have been observed elsewhere; in a systematic review spanning 34 years (1969–2003), Issenberg and colleagues¹⁹ also illustrated the rapid increase in journal articles on high-fidelity simulation in medical education with 57% of the included studies published in the latter years of the review (2000–2003). Although there is a subsequent decline in publications after the peak years of 2004/2006, this can be expected as a consequence of the impact of a time of publication bias that exists within citation analyses, whereby older publications have had more time to accrue more citations than recent studies.¹¹⁹

Strengths and Limitations

Strengths of the study include the following: the use of an accepted and frequently used technical method^{119,120}; stringent, transparent inclusion and exclusion criteria; a comprehensive systematic search process across two key electronic databases; and the presentation of a novel overview and synthesis within the field.

There were also some limitations that should be noted. First, the search was limited to the English language, and so articles in other languages, which may have global impact, were potentially excluded. Second, the citation counts provided by Scopus, Web of Science, and Google Scholar and the records returned by Scopus and Web of Science vary considerably, making it impossible to produce a single comprehensive list of the 100 most cited articles. There are various arguments in favor of and against both Scopus and Web of Science, so it is unlikely that one database is superior to the other.⁷ For example, Web of Science's coverage spans as far back as 1900, whereas coverage of articles before 1996 is more limited in Scopus.^{7,121} However, Scopus covers more journals,¹⁴ including many key simulation journals, which Web of Science does not. For this reason, the list of the top 100 articles is based on Scopus. A further limitation is that the methodological rigor of the included studies was not examined. An assessment of study quality would have allowed for the examination of the association between citation count and study quality as well as the determination of whether high quality studies receive more citations. This is something that future research may wish to address.

Finally, there are limitations to the assumption that highly cited articles are highly influential. First, different disciplines/domains often have different rates of citations, which makes cross comparison difficult. For example, even within the same specialties, different citation rates can be found in different countries.¹²² Second, the size and type of specialty also influence citation rates, whereby larger fields, with more journals, tend to have higher citation rates because of the increased opportunity to gather citations.¹²³ Likewise, there is a risk of bias in relation to the time of publication, whereby older publications have had longer to accumulate citations. Citation

practices of individuals can also affect citation rates. For example, formal citations are not always correctly cited and informal citations, such as grey literature or conference presentations, do not get routinely cited.¹¹⁴ Biased citing can also occur because of Halo and Mathew effects or self/in-house citing and can affect overall counts.^{8,124,125} However, within our data set, the rates of self-citations were relatively low (<6%). Finally, there are considerable variations in the items retrieved from different databases, as observed in the present study, and at different time points.¹²⁶ It should also be noted that there are alternative methods of conducting bibliometric analyses to the method employed in the current study.¹²⁷ For example, impact may be measured based on the mean citations per year or via the number of article views. Nevertheless, citation analysis is a key methodology used across many disciplines,¹²⁷ and despite the previously mentioned limitations, when applied appropriately, citation analysis can be a useful approach to identify which authors, articles, and topics are influencing or motivating research in a field.^{9,10}

Implications for Future Research

This review has provided an historical overview of the highly cited publications within the field of healthcare simulation education and research, as opposed to looking to the future of the field. Nevertheless, based on our findings, it is possible to provide some thoughts on what we may see as the field of simulation continues to advance. Healthcare simulation research has clearly matured for the last three decades, with the top 10 articles all being published within the last 20 years. There is now sufficient evidence that healthcare simulation is an effective educational intervention when it is used under the right conditions.¹²⁸ Therefore, there will be a move away from research questions focused on “does healthcare simulation work?” to an assessment of the conditions when simulation is most effective, ie, “why, how, and with whom does healthcare simulation work?”

We anticipate an increasing number of systematic reviews and meta-analyses within specific areas of healthcare simulation such as those by McGaghie et al³³ and Sturm et al.¹¹² Until recently, there may not have been a sufficient number of journal articles to allow for these types of reviews. However, as the body of research increases, these types of reviews will become more commonplace in the healthcare simulation literature.

It is likely that surgery will continue to be a dominant specialty in the most cited healthcare simulation research, with a growing role for simulation across surgical specialties.²⁸ Simulation is a potentially effective training and education tool to support the continued growth in MIS, and other new surgical methods (eg, robot-assisted surgery) are also techniques that can be taught and practiced using simulators.¹²⁹

With further advances in healthcare simulation technology (eg, improved haptics), it is also likely that there will be a “blurring” of the categories of simulators and increases in the use of hybrid simulation (ie, the combination of two or more simulation modalities to create a more realistic experience,¹¹⁵ such as those used by Kneebone et al¹²⁹ and Crofts et al¹³⁰), and VR simulator technologies such as the MIST-VR for surgical training (eg, Aggarwal et al⁶⁹ and Grantcharov et al¹⁰⁹).

CONCLUSIONS

The use of healthcare simulation is no longer an exception but has become a key component of modern health profession education and training.^{13,131} This review has demonstrated that healthcare simulation is a vibrant and growing field of research. As the use of healthcare simulation has become more commonplace in healthcare education, there has been an exponential rise in the number of research articles published and a corresponding increase in the outlets that publish this research. Healthcare simulation will always be changing and developing.¹²⁸ However, it is hoped that identifying those articles that have had the most influence during the last decades will help inform the healthcare simulation research that will be carried out in the future.

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