Journal of Spine Practice July 2023
DOI: 10.18502/jsp.v2i2.12627

JOURNAL of SPINE PRACTICE

Original Article

Three decades of spine surgery research evolution in Saudi Arabia: A bibliometric analysis

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Background

Over recent decades, there has been a constant increase in the numbers and quality of spine surgery research. We herein plan to analyze the evolution of spine surgery-related publications from Saudi Arabia for three decades.

Materials and Methods

A systematic review of the literature with predefined inclusion criteria was carried out, utilizing multiple significant databases (PubMed, Google Scholar, and Embase). Multiple search terms were used to retrieve related articles. Numerous variables were collected and analyzed, such as articles' level of evidence, citation numbers, study design, and author-related information. For comparison, the study period was divided into three time frames: 1990–2000, 2001–2010, and 2011–2022.

Results

Out of 2969 articles, only 254 met the inclusion criteria of the current study. During the period 2011–2022, an increase of 41% was observed in the number of publications. The highest number of publications was in 2020 (n = 36, 14.2%). Level IV comprised the highest percentage (n = 130, 51%). High-quality articles (Levels I and II) had increased (11%) from 2011 to 2022. The most commonly utilized study design was case reports (44%). Seven randomized controlled trials were identified during the study period. Most of the included articles were from Riyadh province (65%). Research interest revolved around general spine care, trauma, and oncology in 2011–2022.

Conclusion

This is the first study to quantitatively analyze spine surgery-related research in Saudi Arabia. However, there has been significant development in several publications in the last decade, but the quality still needs to be improved. Therefore, we should aim to produce higher-quality studies to meet the country's 2030 vision goals to be one of the leading nations in spine surgery practice.

Keywords: *Spine surgery, Bibliometric, Quality, Evolution, Saudi Arabia, Neurosurgery, Orthopedics.*

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Article History
Published: 4 July 2023

How to cite this article: Maghrabi, Ashgar M, Aljohani S, Alqarni R, Baeesa S. Three decades of spine surgery research evolution in Saudi Arabia: A bibliometric analysis. J Spine Pract 2023;2:51–60.
DOI: https://doi.org/10.18502/jsp.v2i2.12627

1. Introduction

In modern medicine, evidence-based practice has become an integral part of daily clinical practice (1). Such practice would guide decision-making to improve patients' care (2). Evidence-based scales measure the quality of evidence to determine the level of evidence a particular study provides (2). Citation numbers measure the impact of certain publications on the global literature, a parameter used to quantify the number of times an article has been cited (3). Multiple studies have been done to measure the quality and impact of specific nations' publications on global spine surgery literature (4–9).

Saudi Arabia is advancing rapidly in multiple sectors, including the health sector, after the initiation of the 2030 vision (10). Thus, measuring the evolution of the field of spine surgery is vital to ensure a high standard of care for the Saudi Arabian population. Measuring publications' quality and impact would achieve such a goal. The authors conducted a similar study (SB, YM) in 2018 (11). Our current study is considered the first to analyze publications' trends over three decades.

We herein aim to evaluate the evolution of Saudi contributions in spine surgery over three decades, measure their impact on global literature, and compare the evolution of Saudi publications over different periods.

2. Materials and Methods

A literature search was conducted using the PubMed database and augmented by a supplementary search in the Google Scholar database to identify spine surgery-related publications from conception (1990 in this paper) to September 2022. The search strategy consisted of computing the search term followed by "Saudi Arabia" (Table I). Abstracts were screened, and the full text of articles meeting the eligibility criteria was accessed (Figure **1**). Citation numbers were imported from Google Scholar. Assessing the quality of articles was carried out by three reviewers, and disagreement was solved by discussion. The level of evidence was graded using Oxford Centre for Evidence-Based Medicine (OCEBM) - Levels of Evidence Scale (Oxford scale). Institutional Review Board approval was not required as the data of this study is available publicly.

Preset inclusion criteria were developed, which included spine surgery-related articles published by physicians specializing in either neurosurgery, orthopedic surgery, rehabilitation and physical therapy, rheumatology, or any other specialties that deal with spine surgery-related cases, from conception, as shown to be 1990 in this paper, to September 2022. Additionally, the first author had to be affiliated with a Saudi institution, with the study population-based in Saudi institutions, either wholly or partially. Systemic reviews and meta-analyses were included since they are of high LOE. In the case of systemic reviews and meta-analyses with international collaboration, at least one author had to be affiliated with a Saudi institution. In addition, a full text of the article had to be available for analysis.

Nonclinical articles such as editorials, literature reviews, animal studies, cadaveric studies, or lab studies were excluded. Moreover, clinical studies published earlier than January 1st, 1990 were also excluded. Finally, studies in which the study population was based in a geographical area outside Saudi Arabia and studies with no available full text were excluded.

Several parameters were collected from each article and entered into a Microsoft Excel spreadsheet. Several variables were collected, such as the journal's name, impact factor, year of publication, first author affiliation, the number of authors, city, study design, level of evidence, and citation numbers. Moreover, each article was then categorized

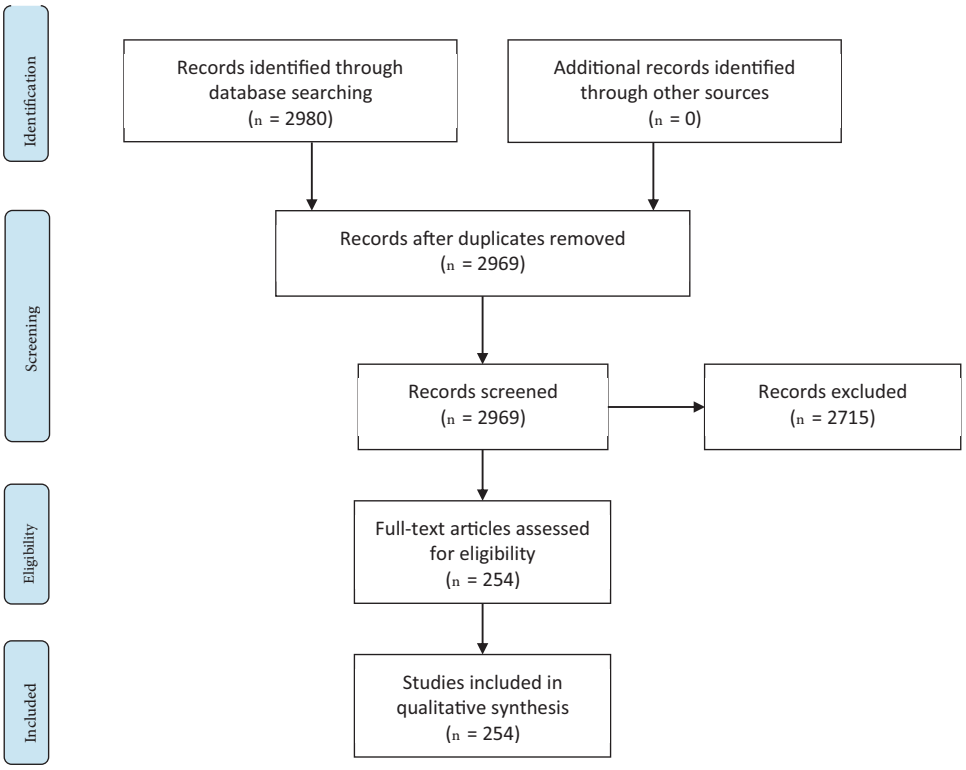

Figure 1. PRISMA schematic representation of the review process.

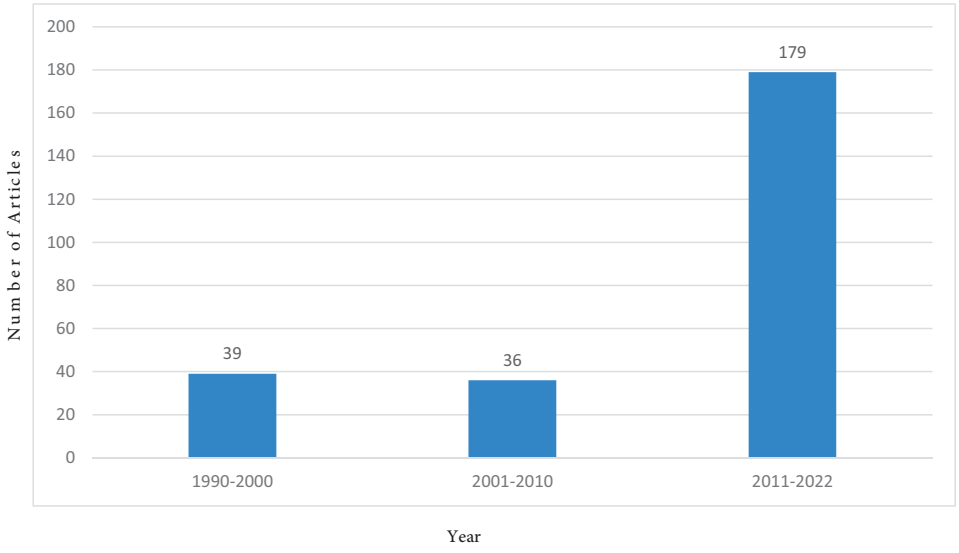

Figure 2. Number of included articles from 1990–2022.

into degenerative, developmental, oncology, trauma, rehabilitation, deformity, rheumatologic pathology, or general spine care. Sectors of the first authors' affiliations were divided into governmental, academic, military, and private practice. Specialties of the first authors were also collected.

Microsoft Excel (Microsoft, Redmond, Washington, USA) was used for the statistical analysis. Continuous data were compared using an unpaired *t*-test, while Chi-square was used for categorical data. A $P < 0.05$ and a confidence interval of 95% were considered statistically significant. Frequency was expressed regarding percentage, and mean and

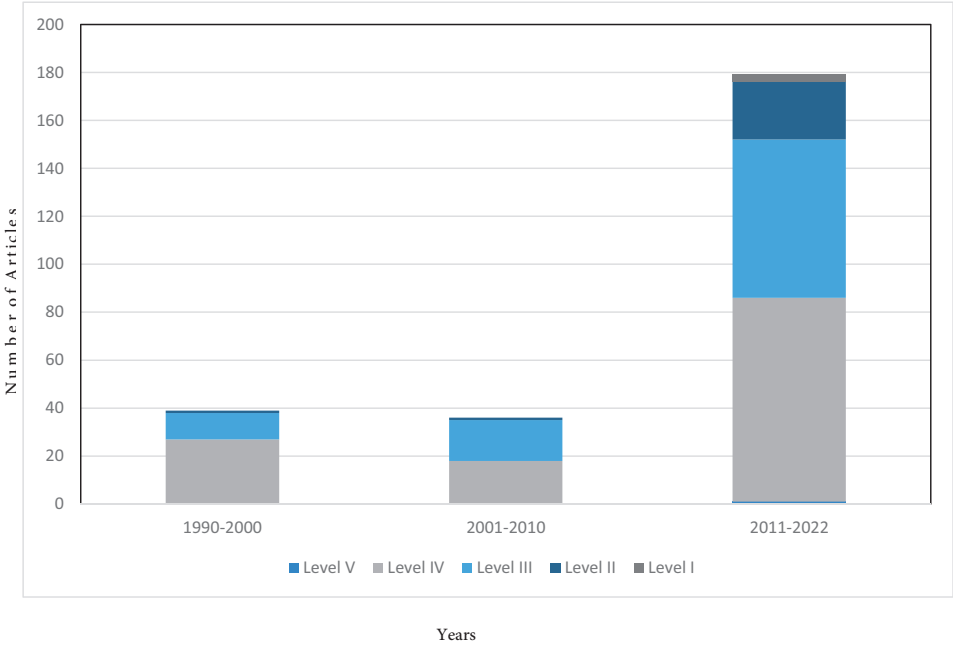

Figure 3. Comparison between three decades worth of Saudi spine surgery publications in terms of frequency and quality (*P*-value < 0.05).

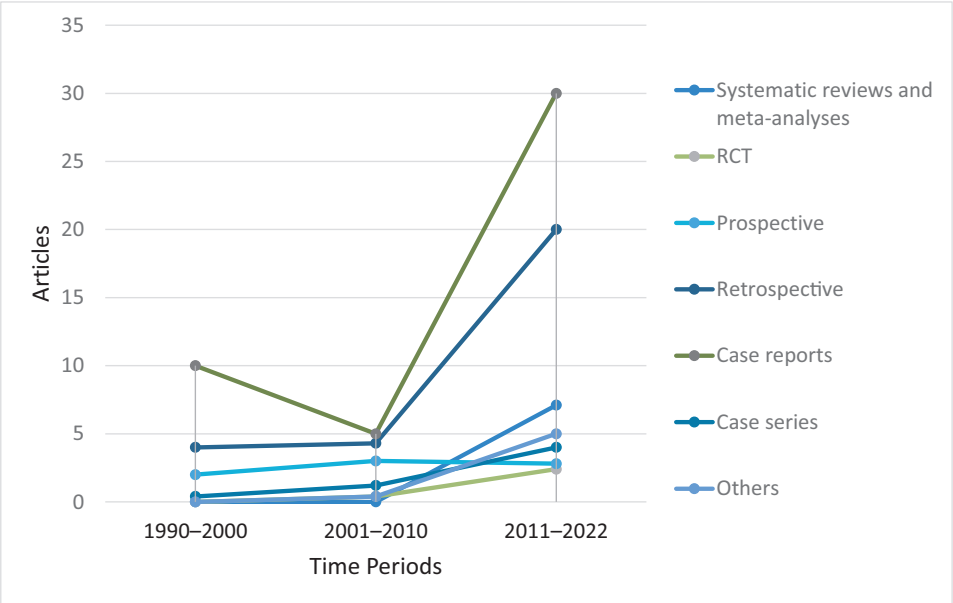

Figure 4. Progression of study design over three decades.

median were the only measures of central tendency utilized for data analysis.

3. Results

Around 2969 articles were screened after duplicate removal. Articles were chosen based on the concurrence of their titles and abstracts with eligibility criteria. In the primary search, only 254 articles met the inclusion criteria, after which full-text versions were accessed to apply the complete list of eligibility criteria. A total of 254 articles were added to the qualitative analysis of this study.

The study period was divided into three time frames (1990–2000), (2001–2010), and (2011–2022) (Figure **2**). An exponential increase was seen in the number of publications from 2011 to 2022 compared to the other two periods, which was around 41%. Another observation was that in the year 2020 (COVID-19 pandemic), the number of publications was the highest among all the study periods (n = 36, 14.2%). While the average number of publications yearly was 3.5 articles in 1990–2000 and 3.6 articles in 2001–2010, it was 15 articles in 2011–2022.

Collectively regarding the quality of included articles, level IV comprised the highest percentage (n = 130, 51%), followed by level III (n = 94, 37%), level II (n = 26, 10%), level I (n = 3, 1.2%), and level V (n = 1, 0.4%). After stratifying the quality of included articles according to periods defined earlier, it would be observed that in 2011–2022 the number of high-quality articles (Levels I and II) had increased to 11% in comparison to 0.4% each in 1990–2000 and 2001–2010, respectively. Moreover, the exponential growth of 30% in the number of low-quality articles (Levels III, IV, and V) was observed in 2011–2022 in comparison to other periods (P-value < 0.05) (Figure **3**).

Most common study design observed was case reports comprising about 44% of included articles (n = 113), followed by retrospective cohort studies (n = 72, 28%), prospective cohort studies (n = 18, 7%), systematic reviews and meta-analyses (n = 17, 6.7%), randomized controlled trials (n = 7, 3%), and others (n = 27, 12%). Looking at the publication trends according to study designs in different periods, it can be observed that most of the systematic reviews and meta-analyses were published from 2011 to 2022 (n = 18, 7.1%). Moreover, 6 (2.4%) randomized controlled trials were conducted during the same period. However, still, the number of case reports prevailed. In the period 2001–2010, case reports and retrospective studies were similar in numbers (4.3% and 4.7%, respectively). In 1990–2000, most of the publications were case reports (10%), with no systematic reviews or randomized controlled trials (Figure **4**).

Citation numbers ranged from 1 to 362 citations per paper, with a median of 4. Around 34 articles included in our study had no citations (Table II). The mean citation number over three decades was 19.43 citations. Comparing the mean citations across our prespecified time frames, we find that the mean citation numbers were the highest in the period 2001 and 2010 comprising around 50.3 citations, followed by 1990–2000 with a mean of 23 citations and 2011–2022 with a mean of 12 citations.

The impact factors (IF) of included journals ranged from 0.089 to 9.2 (median 1.48). The average IF over three decades was 1.85, and 11 journals had no recorded IF. Comparing the IF across different time frames, it was found that the period 1990–2000 had the highest mean of 2.34. However, no significant difference was between 2001–2010 and 2011–2022 (1.87 and 1.75, respectively). The top five used journals were the *Spine Journal* (n = 16, 6.3%), *Neuroscience* (Riyadh) (n = 15, 6%), *Saudi Medical Journal* (n = 14, 5.5%), *British Journal of Neurosurgery* (n = 8, 3%), *European Spine Journal* (n = 8, 3%), and *Cureus* (n = 7, 3%). The rest (73%) were published in 101 journals.

Regarding study types, 57% of studies were epidemiological studies, followed by prognostic studies (18%), therapeutic (16%), and diagnostic studies (9%). The most discussed topics related to spine surgery were as follows – general spine surgery care (41%), spinal trauma (18%), spinal oncology (13%), developmental spinal conditions (10%), degenerative spine diseases (8%), spinal deformity (6%), and spinal vascular conditions (4%) (Figure **5**). The anatomical focus of included articles was mixed in 36% of papers, followed by the cervical spine in 24%, thoracic in 11.4%, lumbar in 11%, and others in 17.6%. The sample size ranged from 1 to 17,047 subjects (mean = 216). The anatomical focus was

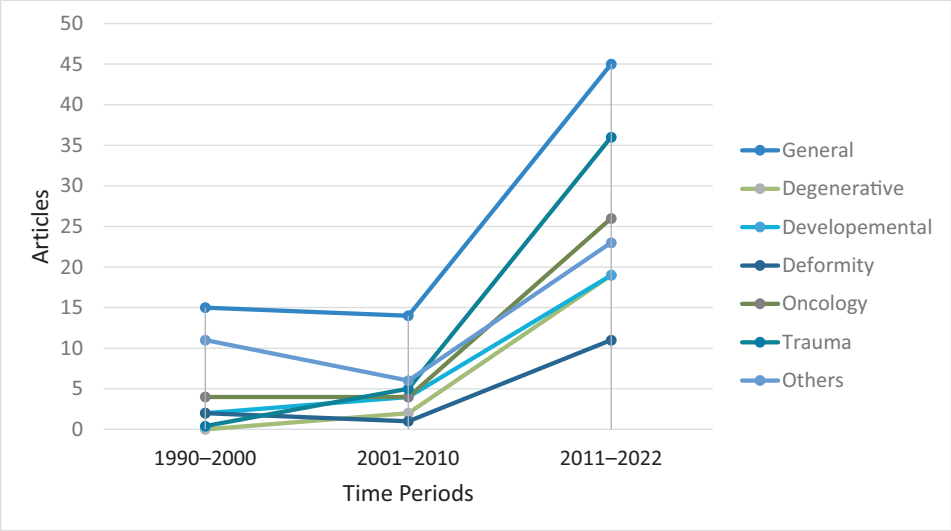

Figure 5. Types of studies according to different time frames.

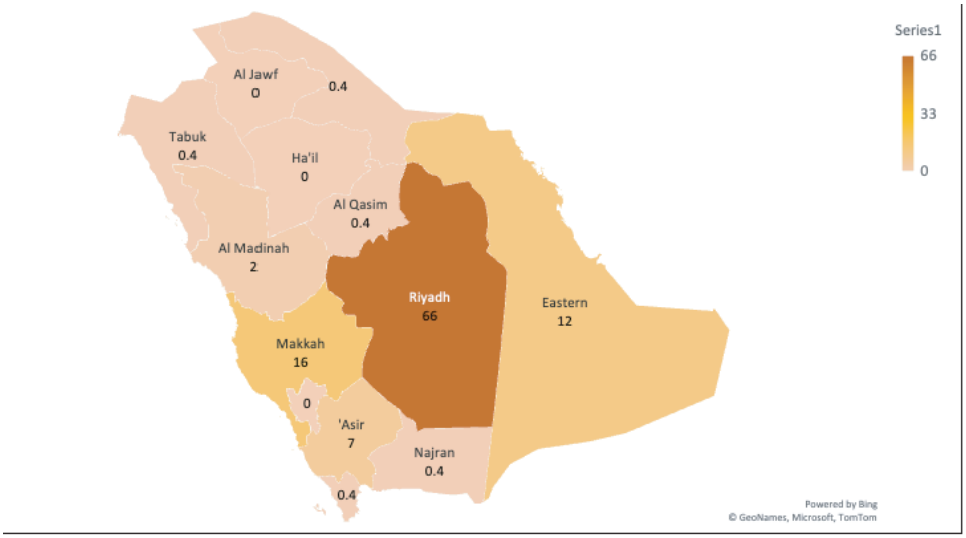

Figure 6. Geographical distribution of percentage of publications according to Saudi Provinces.

Table I. Search terms used in the acquisition of the data of this study.

Terms
Spine fusion – Spinal fusion – Spine fixation – Spinal fixation – Spine surgery – Spinal surgery – Herniated disc – Herniated disk – Disc degeneration – Disk degeneration – Discectomy – Laminectomy – Spinal stenosis – Spinal cord – Spondylitis – Spondylolisthesis – Spondylolysis – Spinal rehabilitation – Spinal injury

not specified in 8% of included publications. The age groups of included populations were adults in 54%, pediatrics in 23%, and mixed in 17%. Age groups were not specified in 6% of the articles.

Most of the articles originated from Riyadh (n = 166, 65%), followed by Jeddah (n = 33, 13%), Al-Khobar (n = 16, 6%), Dammam (n = 10, 4%), and others (n = 29, 11%). In the periods between 1990–2000 and 2001–2010, a pattern was observed that most publications output was from Riyadh (24 articles in 2001–2010 and 29 articles in 1990–2000) followed by Al-Khobar (6 articles in 2001–2010 and 7 articles in 1990–2000), with few reports from other different cities such as Jeddah, Makkah, Dammam,

Table II. The 25 most cited spine surgery articles in Saudi Arabia.

Rank	Article	CN	Study type	LOE
1	Al Faraj S, Al Mutairi K. Vitamin D deficiency and chronic low back pain in Saudi Arabia. *Spine* 2003; 28(2): 177–179.	362	Epidemiologic	III
2	Elwatidy S, Jamjoom Z, Elgamal E, Zakaria A, Turkistani A, El-Dawlatly A. Efficacy and safety of large prophylactic dose of tranexamic acid in spine surgery: A prospective, randomized, double-blind, placebo-controlled study. *Spine* 2008; 33(24): 2577-80.	247	Therapeutic	II
3	MacDonald DB, Al Zayed Z, Khoudeir I, Stigsby B. Monitoring scoliosis surgery with combined multiple pulse transcranial electric motors and cortical somatosensory-evoked potentials from the lower and upper extremities. *Spine* 2003; 28(2): 194–203.	241	Prognostic	III
4	Ardawi MS, Akhbar DH, Alshaikh A, Ahmed MM, Qari MH, Rouzi AA, et al. Increased serum sclerostin and decreased serum IGF-1 are associated with vertebral fractures among postmenopausal women with type-2 diabetes. *Bone* 2013; 56(2): 355–362.	182	Diagnostic	III
5	Alothman A, Memish ZA, Awada A, Al-Mahmood S, Al-Sadoon S, Rahman MM, et al. Tuberculous spondylitis: Analysis of 69 cases from Saudi Arabia. *Spine* 2001; 26(24): E565–E570.	149	Epidemiologic	III
6	Najjar MW, Baeesa SS, Lingawi SS. Idiopathic spinal cord herniation: a new theory of pathogenesis. *Surg Neurol* 2004; 62(2): 161–70; discussion 70–71.	105	Epidemiologic	IV
6'	Jamjoom ZA. Acute spontaneous spinal epidural hematoma: The influence of magnetic resonance imaging on diagnosis and treatment. *Surg Neurol* 1996; 46(4): 345–349.	105	Diagnostic	IV
7	Orief T, Orz Y, Attia W, Almusrea K. Spontaneous resorption of sequestrated intervertebral disc herniation. *World Neurosurg* 2012; 77(1): 146–152.	95	Epidemiologic	IV
8	Al-Mulhim FA, Ibrahim EM, El-Hassan AY, Moharram HM. Magnetic resonance imaging of tuberculous spondylitis. *Spine* 1995; 20(21): 2287–2292.	89	Diagnostic	III
9	Anwer S, Alghadir A, Abu Shaphe M, Anwar D. Effects of exercise on spinal deformities and quality of life in patients with adolescent idiopathic scoliosis. *Biomed Res Int* 2015; 2015: 123848.	79	Prognostic	II
10	Macdonald DB, Al Zayed Z, Al Saddigi A. Four-limb muscle motor evoked potential and optimized somatosensory evoked potential monitoring with decussation assessment: Results in 206 thoracolumbar spine surgeries. *Eur Spine J* 2007; 16(2): S171–S187.	78	Prognostic	III
11	Kanaan IU, Ellis M, Safi T, Al Kawi MZ, Coates R. Craniocervical junction tuberculosis: A rare but dangerous disease. *Surg Neurol* 1999; 51(1): 21–25; discussion 6.	71	Epidemiologic	IV
12	Sadat-Ali M, Al-Othman A, Bubshait D, Al-Dakheel D. Does scoliosis cause low bone mass? A comparative study between siblings. *Eur Spine J* 2008; 17(7): 944–947.	69	Epidemiologic	III
13	Naim Ur R, El-Bakry A, Jamjoom A, Jamjoom ZA, Kolawole TM. Atypical forms of spinal tuberculosis: Case report and review of the literature. *Surg Neurol* 1999; 51(6): 602–607.	64	Epidemiologic	IV
14	Alshami AM. Prevalence of spinal disorders and their relationships with age and gender. *Saudi Med J* 2015; 36(6): 725–730.	62	Epidemiologic	III
15	Al-Sebai MW, Al-Khawashki H, Al-Arabi K, Khan F. Operative treatment of progressive deformity in spinal tuberculosis. *Int Orthop* 2001; 25(5): 322–325.	62	Therapeutic	III
16	Alshahri SS, Cripps RA, Lee BB, Al-Jadid MS. Traumatic spinal cord injury in Saudi Arabia: An epidemiological estimate from Riyadh. *Spinal Cord* 2012; 50(12): 882–884.	60	Epidemiologic	III
17	Alqarni AM, Schneiders AG, Cook CE, Hendrick PA. Clinical tests to diagnose lumbar spondylolysis and spondylolisthesis: A systematic review. *Phys Ther Sport* 2015; 16(3): 268–275.	58	Diagnostic	II
18	Al-Habib AF, Attabib N, Ball J, Bajammal S, Casha S, Hurlbert RJ. Clinical predictors of recovery after blunt spinal cord trauma: systematic review. *J Neurotrauma* 2011; 28(8): 1431–1443.	57	Prognostic	II
19	Behairy YM, Al-Sebai W. A modified technique for harvesting full-thickness iliac crest bone graft. *Spine* 2001; 26(6): 695–697.	46	Therapeutic	III
20	Al-Mohrej OA, Aldakhil SS, Al-Rabiah MA, Al-Rabiah AM. Surgical treatment of adolescent idiopathic scoliosis: Complications. *Ann Med Surg* 2020; 52: 19–23.	44	Prognostic	III
21	Naim Ur R, Salih MA, Jamjoom AH, Jamjoom ZA. Congenital intramedullary lipoma of the dorsocervical spinal cord with intracranial extension: Case report. *Neurosurgery* 1994; 34(6): 1081–1083; discussion 4.	44	Epidemiologic	IV
22	Jamjoom BA, Jamjoom AB. Efficacy of intraoperative epidural steroids in lumbar discectomy: A systematic review. *BMC Musculoskelet Disord* 2014; 15: 146.	38	Therapeutic	I
23	Naim Ur R, Jamjoom A, Jamjoom ZA, Al-Tahan AM. Neural arch tuberculosis: Radiological features and their correlation with surgical findings. *Br J Neurosurg* 1997; 11(1): 32–38.	35	Epidemiologic	III
24	Al-Sebai MW, Al-Khawashki H. Spondyloptosis and multiple-level spondylolysis. *Eur Spine J* 1999; 8(1): 75–77.	34	Diagnostic	IV
24'	Al-Arjani AM, Al-Sebai MW, Al-Khawashki HM, Saadeddin MF. Epidemiological patterns of scoliosis in a spinal center in Saudi Arabia. *Saudi Med J* 2000; 21(6): 554–557.	34	Epidemiologic	III
25	Awada A, Russell N, Al Fayez N, Naufal R, Al Kohlani H. Spontaneous cervical epidural hematoma: Case report. *Spinal Cord* 1998; 36(1): 71–72.	33	Epidemiologic	IV

CN: Citation number

and others (Figure **6**). However, looking at 2011–2022, a different pattern emerges in the number of publications, research output from new cities, and

decreased output from other cities. Riyadh has the top research output of 113 articles; Jeddah came second with exponential growth from 3 articles in 1990–2010 to 30 articles in 2011–2022, 9 articles from Dammam, 7 articles from Abha, and 7 articles from Makkah. Of note, the number of publications from Al-Khobar decreased to 3 (2011–2022).

The top five affiliations with the highest number of publications include King Saud University (KSU) with 45 publications (18%), King Abdelaziz medical city of the national guard in Riyadh with 25 publications (10%), King Fahad Medical City (KFMC) and King Faisal Specialist Hospital and Research Center Riyadh (KFSHRC) with 23 publications each (9% each), Imam Abdulrahman Bin Faisal University (IAU) 21 publications (8%), and King Abdulaziz University (KAU) 19 publications (7%).

According to the inclusion criteria, the first author's specialty was as follows: neurosurgery at 41%, orthopedics at 26%, physical medicine and rehabilitation at 11%, neurology at 6%, and other specialties at 16%. The top authors with the highest number of publications were A. Al-Habib (n = 9, 4%), K. AlSaleh (n = 8, 3%), N. Naim-Ur-Rahman (n = 8, 3%), A. Bourghli (n = 7, 2.7%), and S. Baeesa (n = 5, 2%).

4. Discussion

The progress of countries, both economically and scientifically, depends on their involvement in research and innovation (6). Bibliometric analysis methods have shown efficacy in assessing research development in specific fields (9). Multiple studies have dealt with the bibliometric analysis of research output from confined geographical areas (4–9). A previous study by the authors of the current study (SB, YM) has found that Saudi research output in spine surgery was low in quality and numbers (11). Another study was done to evaluate the quality of spine surgery research in Arab countries, which found that the quality of research output was low comparing 15 years of publications (12). The current study is considered the first to evaluate research output over three decades (1990–2022). The main aim was to evaluate the number of publications, evaluation of the quality of publications, and the impact of publications originating from Saudi Arabia on the global spine literature.

Looking at the number of publications according to different time frames, it has been observed that the increase was exponential, making around 41% compared to the time from 1990 to 2010 (Figure **2**). Another observation that can be made is that in the year 2020 (COVID-19 pandemic), the number of publications was the highest across the study period making about 14.2%. Regarding quality, level IV composed the highest percentage, 51%, comparable to other global studies (4–7). Therefore, the exponential growth of 30% in the number of low-quality articles and the increase in the number of high-quality articles by 11% would make an exciting trend in Saudi publications in 2011–2022 compared to 1990–2000 and 2001–2010. The article with the highest impact (citation number 362) was produced by Al Faraj and colleagues, investigating the role of Vitamin D on chronic low back pain (13).

Trends in research interest in spine surgery in Saudi Arabia have shifted, as can be observed in Figure **5**. General spine surgery topics have been the most discussed topics in included publications. Interestingly, spinal trauma was low on the list in 1990–2010 but jumped to second place in 2011–2022. Another interesting observation is that there has been increasing interest in spinal oncology care in the last 10 years, owing to the improvement of cancer care in Saudi Arabia.

Multiple factors would have played a role in such improvement in numbers and quality; firstly, the training of medical students on evidence-based

medicine (EBM), as it is a core topic of the undergraduate medical school curricula in Saudi Arabia (14). The other contributing factor is the particular emphasis from the Saudi commission for health specialties (SCFHS) on research contribution for the applicants for the Saudi board in both neurosurgery and orthopedics and the minimal requirement for the specific programs for board certification (11). Another contributing factor was the increasing number of internationally trained Saudi spine surgeons with good research training joining the workforce and contributing with large numbers of publications. Finally, since the introduction of the 2030 vision in the healthcare reformation plan in 2016, the Saudi government put into its mission to provide high-standard care based on the latest well-recognized evidence from global literature, which can be evident from our results that the increase in the number of publications and improving quality happened after 2016 (Figures 2–4).

Global spine literature suffers from several weaknesses that are not exclusive to Saudi spine literature only. One of these is the publications of low-quality articles, as put by Falavigana et al., that spine surgeons prefer such types of articles due to lack of funding, lack of time, lack of interested mentors, and lack of incentives (4, 6). However, with the establishment of the Saudi national institute of health (SNIH), many of the problems mentioned earlier could be overcome, as such a governmental body could help in funding, training, and promoting research activities across different specialties in the medical field.

This study has limitations, the first being the limited search on papers indexed in PubMed and Google Scholar since the papers published in journals not indexed in the two databases might have been missed. The other limitation is the reliance on citation numbers imported from Google Scholar, as no detailed analysis of citations can be inferred since only a rough estimate is provided.

5. Conclusion

In conclusion, improvement in the numbers and quality of published spine surgery research in Saudi Arabia can be observed over three decades. Different governmental bodies have also established research infrastructure in recent years. Therefore, we should aim to produce higher-quality studies to meet the country's 2030 vision goals and be one of the leading nations in spine surgery practice.

Acknowledgments

None.

Conflict of Interest

None.

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