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Original Article

Orthopedic research productivity of KSA: First bibliometric analysis

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الملخص

أهداف البحث: البحث الطبي هو مؤشر مهم لسمعة الأمة وتطورها. وهناك مخاوف بشأن محدودية الأبحاث المتعلقة بتخصص جراحة العظام في المملكة العربية السعودية. لذلك، في هذه الدراسة، تم إجراء تحليل إحصائي (ببليومتري) للتحقق من مخرجات أبحاث العظام في المملكة العربية السعودية.

طرق البحث: تم البحث في قاعدة بيانات (بوب مید) للأبحاث المتعلقة بجراحة العظام، التي تضم على الأقل مؤلفًا واحدًا متخصصًا في جراحة العظام تابعًا للمملكة العربية السعودية، وتم نشره منذ عام ٢٠٠٠ فصاعدًا. وقد استبعدت هذه الدراسة المقالات المكررة، والتصحيحات، والرسائل، والافتتاحيات، والتعليقات، والاتصالات الموجزة. كما تمت الإشارة إلى عناوين المقالات المضمنة، وسنوات النشر، والانتماءات الأساسية للمؤلفين الأوائل والبلدان التي ينتمي اليها الباحثون، وإجمالي الاستشهادات. بعد ذلك، تم تحليل الإسهام البحثي على مدار العام، وأفضل الدول المسهمة والمتعاونة، وأفضل الانتماءات المسهمة، وأنواع الدراسات، ومستويات الأدلة، وتوزيع المجلات، والمعلومات المتعلقة بالربع، واتجاهات الاستشهاد وعامل تأثيرها.

النتائج: أسفرت استراتيجية البحث عن وجود ١٠٤٧ بحثاً منشوراً. وقد لوحظ اتجاه متزايد في الإسهامات البحثية في السنوات الأخيرة، حيث كان الإسهام بأقل عدد من الأبحاث (٨) في عام ٢٠٠٥ وأكثرها (١٤٠) في عام ٢٠٢٣. وتم إجراء أغلب الأبحاث المنشورة في المملكة العربية السعودية (٨٣.٤٨٪). وكانت أعلى نسبة تعاون مع مؤلفين من خارج السعودية كانت من دولة كندا بنسبة ٣.٤٤٪ من الأبحاث. وكانت جامعة الملك سعود هي المؤسسة الأكثر إسهاما في عدد الأبحاث المنشورة (١٧.٣٨٪).

بالنسبة لمواضيع الدراسات المنشورة فقد كان منها ٦٦ (٦.٣٪) متعلقا بالعلوم الأساسية، و٨٧٣ (٨٣.٣٪) بحثا متعلقا بالدراسات السريرية التي كان أغلبها (٨٤.٥١٪) تصنف من المستوى الرابع من ناحية قوة مستوى الأدلة. ٧٣٪ من جنسية الباحثين والمؤلفين الأساسين للأبحاث المنشورة من المملكة العربية السعودية. بشكل عام، تم نشر ٣١.٢٣٪ من المقالات التي تحتوي على معلومات ربعية متاحة في مجلات الربع الأول.

الاستنتاجات: إن إنتاجية أبحاث جراحة العظام في المملكة العربية السعودية محدودة. ولكن هناك تزايد ملحوظ في إنتاجية أبحاث جراحة العظام في السنوات الأخيرة. ومع ذلك، فإن جودة البحوث السريرية، وخاصة مستوى الأدلة، تحتاج إلى تحسين. ولذلك، ينبغي بذل المزيد من الجهود لتعزيز فرص البحث وتشجيع المشاركة البحثية بين المراكز الطبية وجراحة العظام.

الكلمات المفتاحية: المملكة العربية السعودية؛ الأبحاث الطبية؛ جراحة العظام

Abstract

Purpose: Medical research is a crucial indicator of a nation's reputation and development. However, there are concerns about the limited orthopedic research in Kingdom of Saudi Arabia (KSA). Therefore, this study conducted bibliometric analysis to investigate orthopedic research output from KSA.

Methods: PubMed database for orthopedic articles, with a minimum of one KSA-affiliated orthopedic author published from the year 2000 onwards, was searched. This excluded duplicate articles, corrections, letters, editorials, commentaries, and brief communications. The titles of the included articles, publication years, first and corresponding authors' primary affiliations and countries, countries and institutes of research, and total citations were noted. Thereafter, year-wise research contribution, top contributing and collaborating nations, top contributing affiliations, study types, levels of evidence, journal distribution, their impact factor, h-index and quartile-related information, and citation trends were analyzed.

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Results: The search strategy yielded 1047 eligible articles. An increasing trend in research contributions in recent years was observed, with the least number of articles (8) contributed in 2005 and the most (140) in 2023. The research was conducted in KSA for most articles (83.48%). Authors from Canada collaborated in 3.44% of the articles. King Saud University was the top contributing institution (17.38% of all articles). There were 66 (6.30%) basic science studies and 873 (83.3%) clinical studies. Among non-basic science studies, 84.51% had level IV evidence. Overall, 73.83% of articles had either first/corresponding or both authorships from KSA-affiliated orthopedic authors. The eligible articles were published in 303 journals, with a mean impact factor of 3.04 (range 0.4-51.1, 165 journals) and a mean h-index of 59.2 (range 1-367, 277 journals). Overall, 31.23% of articles with quartile information available were published in first-quartile journals.

Conclusions: The orthopedic research productivity in KSA is limited. However, there has been an increasing trend in orthopedic research in recent years. Nevertheless, the quality of clinical research, particularly the level of evidence, needs improvement. Therefore, further efforts should be made to strengthen research opportunities and encourage research participation among orthopedic and medical institutes.

Keywords: Author; Bibliometric analysis; KSA; Medical research; Orthopedic; Productivity

Introduction

Medical research, a crucial indicator of a nation's reputation and development, reflects the quality of healthcare and efficient policies by providing information about disease trends, treatment outcomes, functional abilities, patterns of care, healthcare costs, and utilization of resources.[1] The clinical sciences are not stagnant but continue to advance with shifts toward new practices and the application of new technologies. Evidence-based research is an important tool in public health policy design. On a large scale, such research aids in the determination of a country's health priorities, and enables multi-sectoral involvement of stakeholders to bridge gaps between research and politics.[1]

Therefore, clinicians must be actively involved in research, to advance scientific awareness and contribute to their specialties. However, the limited quality and quantity of medical research conducted in Kingdom of Saudi Arabia (KSA) and other Arab countries is concerning.[2] This concern extends to the orthopedic field.[3] Additional concerns are related to KSA-affiliated authors' preferences for publishing in local and regional journals with low impact factors.[4] Although local authors prefer regional journals, particularly when discussing issues of local importance, considerable contributions should be made to international journals, particularly those with better metrics.

The importance of medical research in national development is evidenced by the substantial consideration of these aspects in Vision 2030, a unique transformative economic and social reform blueprint launched in 2016 to help KSA meet global standards.[5] Research and development, and improved healthcare are integral to this program.[5] One of the program's goals is for five Saudi universities to rank among the top 200 universities worldwide. Moreover, over the past decade, increased gross domestic product (GDP) expenditure in the health sector has been observed (source: World Bank). The health sector's GDP share increased from 4.21% in 2000 to 5.9% in 2021. Health expenditures also cover health care, legislation, and research. Consequently, increasing contributions to medical research have been observed in recent years.[6]

However, an objective analysis is necessary to understand the extent to which research output has improved, in terms of both quality and quantity. In the field of medical education and research, productivity can be assessed through various methods.[6] One acceptable method is assessing the number of publications and the quality of the research through bibliometric analysis.[4,6,7] Bibliometrics is often used to map the literature in a research field, because it yields insights into the focus of research and the development of future trends.[8,9] The journal's impact factor, h-index, and quartile are widely recognized indicators of journal quality and popularity.[10,11] Bibliometric analysis of these parameters can aid in understanding the quality of research work.

Currently, a comprehensive bibliometric analysis of orthopedic research productivity in KSA is lacking. Such an analysis would help identify research growth and contributing factors. In addition, insufficiencies in the current orthopedic research output could be identified and improved through corrective measures. Therefore, we conducted a bibliometric analysis to investigate the research output of orthopedic authors in KSA from the year 2000 onward.

Materials and Methods

Main search strategy

On June 30, 2024, a comprehensive search of the PubMed database for articles published on January 1, 2000, onward was conducted with the following keywords with specified Boolean operators: ((Saudi Arabia) OR (KSA)) AND ((Orthopaedics) or (Orthopedics)) (Figure 1). The search results were downloaded in Microsoft Excel Ver. 16.59. On the basis of the information in the PubMed records for individual articles, the search results were individually screened for articles with at least one author with an orthopedic affiliation primarily in KSA.

Inclusion criteria

The analysis included orthopedic and related articles (related to orthopedics, musculoskeletal medicine or surgery, musculoskeletal rehabilitation, or musculoskeletal-related biomechanics and basic sciences) contributed by at least

one orthopedic author with a primary affiliation in KSA. Surgeons/consultants/faculty/trainees/residents affiliated with an orthopedic department or its subspecialties were considered orthopedic authors. Medical students, interns, and authors without any departmental information, and those affiliated with any non-orthopedic departments, were considered non-orthopedic authors.

Exclusion criteria

Articles were excluded sequentially in the following order:

1. Duplicate articles, corrections of already published articles, comments, brief communications, editorials, letters, and replies
2. Articles without any authors with affiliations in KSA
3. Articles with orthopedic authors with affiliations in KSA, on a research topic outside the musculoskeletal or orthopedic clinical or basic sciences
4. Orthopedic or related articles by Saudi authors with affiliations outside KSA affiliations
5. Orthopedic or related articles with non-orthopedic authors with affiliations in KSA.

Two authors independently conducted the search. The final list was prepared after any discrepancies were resolved through mutual agreement with other reviewing authors.

Secondary search

During a preliminary analysis conducted during the research planning phase, we identified several instances in which orthopedic authors' departmental information was missing from the PubMed record. Therefore, for orthopedic-related articles with authors based in KSA with incomplete departmental information, two authors independently searched the authors' names on related institutional websites to identify any orthopedic or subspecialty affiliation. In addition, to prevent these issues from limiting the search results because of a lack of specification of "orthopedic" or "orthopaedic" terms in the PubMed records of orthopedic-related articles, we conducted a separate PubMed search without including the keywords "orthopaedics"/"orthopedics." Moreover, in some instances, the author names were in reverse order (first name followed by last name, or last name followed by first name). In some cases, middle names were not specified. To expand the search to yield better results without missing any orthopedic articles because of differing orthopedic author name formats, we conducted three additional searches by using all KSA-based orthopedic author names obtained from the above-specified main search strategy. The additional searches were as follows: a) (full author name) AND ((Saudi Arabia) OR (KSA), b) (author's "first name" <space> "last name") AND ((Saudi Arabia) or (KSA)), and c) (author "last name" <space> "first name") AND ((Saudi Arabia) or (KSA). Additional eligible articles were included in the analysis according to the above-specified criteria.

Data collection

The following parameters from the included articles were recorded.

Main information: This information included the title of the article; year of publication; first and corresponding authors' primary affiliations and countries; countries and institutes in which the research was conducted; contributing institutes in KSA for research conducted in other countries; total citations according to the PubMed record; and the roles of KSA-affiliated orthopedic authors as the first author, corresponding author, or both.

Additionally, relevant non-orthopedic specialties and the institutes in which orthopedic research was conducted were recorded. For research conducted in KSA, the institutes and countries of contributing non-Saudi Arabian authors were recorded. If the institutes where the research was conducted were not provided in the abstract, we screened the full texts of the selected articles. For articles without clear information regarding the research locations, the location was recorded according to the information provided in the ethical approval/funding/acknowledgment/address for communication/reprints (in that order). The affiliations were recorded on the basis of the highest institutional level affiliation, that is, the associated university, when this information was available. For non-university affiliations, the available institute names were recorded. The final affiliations were verified on institutional websites for any change in institute name during the study cross-section, to avoid duplicate entries.

Research quality: This information included the type of study (randomized controlled trials, prospective comparative studies, retrospective comparative studies, case series, case reports, cross-sectional studies, systematic reviews, meta-analyses, narrative reviews, guidelines, or basic science studies); level of evidence for clinical studies, according to the *Journal of Bone and Joint Surgery* ranking system for orthopedics[12]; source journals; and main orthopedic subspecialty of research articles, categorized into general topics, adult trauma, arthroplasty, spine, pediatric orthopedics, musculoskeletal oncology, hand and upper extremity, arthroscopy and sports, foot and ankle, deformity, and orthopedic training/education-related research. The general topic category included articles whose orthopedic research topics could not be classified into the remaining subspecialties or multiple involved subspecialties, and had no specific relation to one particular specialty. Two authors performed the categorization into orthopedic specialties, on the basis of mutual agreement. For additional classification, the published articles were considered original articles when they indicated a research question, aim, methods, results, or conclusions of a research study, or experiments conducted by the authors. Systematic reviews and meta-analyses were considered original articles, on the basis of their methods. The other types of review articles, i.e., narrative reviews and expert opinions, were considered review articles rather than original research articles. The source journals were searched on https://www.

scijournal.org/ to determine impact factor and h-index information, and on https://www.scimagojr.com/ to determine quartile information. The impact factor, a scientometric index calculated by Clarivate, reflects the annual mean number of citations of articles published in the prior 2 years in a given journal, as indexed by Clarivate's Web of Science. The 2023 impact factor was considered for the current analysis (source: 2023 Journal Impact Factor, Journal Citation Reports Science Edition (Clarivate Analytics, 2023)). The h-index value is the number of articles (h) published in a journal that have been cited at least h times. The h-index information available in June 2024 was considered for the analysis (source: https://www.scimagojr.com/). The quartiles indicate journal rankings within orthopedics or its subspecialty-related categories. The quartiles rank journals from highest to lowest according to their impact factors and citations (source: https://www.scimagojr.com/). The ranks were divided into four quartiles: Q1, Q2, Q3, and Q4, where Q1 indicated the top 25%, and Q4 indicated the bottom 25% of journals in orthopedics or its subspecialty-related categories. Quartile information available in June 2024 was considered in the analysis. In addition, we reviewed all journals publishing the eligible articles for their subject areas, according to the information on the journals' websites.

Statistical analysis

A descriptive statistical analysis was performed in Microsoft ® Excel Ver.16.59. Continuous variables are reported as mean (range), and discrete variables are expressed as proportions or frequency distributions, as appropriate.

The annual publication growth rate for each year (as a percentage) was calculated as $100 \times (b - a)/a$, where "a" is the number of published articles in the preceding year, and "b" is the number of published articles in the year being analyzed.[13]

Year-wise trends: We created line charts of the numbers of eligible articles published each year, the total number of citations generated by the eligible articles every year, and the level of evidence of articles published each year. The annual citation rate (citations per year after publication) was calculated as the number of citations generated by articles published in a given year, divided by the number of years that had elapsed after the publication year.

Distribution characteristics: We used distribution charts (bar diagrams or pie charts) to describe the distribution of studies in terms of country; countries collaborating in research conducted in KSA; institutes/universities in which studies were conducted; types of publications and their evidence levels; journal names and quartiles; specialties and orthopedic subspecialties (subject area); numbers of citations for various subspecialties; and roles of KSA orthopedic authors (first/corresponding/other) in the eligible articles.

List of abbreviations

ASCR	Arthroscopic superior capsule reconstruction
GDP	Gross domestic product
ICMJE	International Committee of Medical Journal Editors

Results

The search strategy yielded 8167 articles published between January 1, 2000, and June 30, 2024. A total of 1047 eligible articles were included. The excluded articles included four duplicate entries, 70 commentaries/letters/editorials/brief communications/corrections, 46 articles without any Saudi authors, 6266 articles unrelated to orthopedics, 503 articles related to orthopedics but without orthopedic authors, and 213 orthopedic articles by Saudi authors with affiliations outside KSA. The detailed search strategy is shown in Figure 1.

The number of orthopedic-related publications by year (Figure 2) indicated visible growth from 2000 until June 30, 2024. The most articles were published in the year 2023. The mean annual growth rate was 20.85% (until 2023) (range −56.52% to 113.04%).

Regional characteristics

The research in the included articles was conducted in 31 countries. KSA was the top research location (83.48% of research articles). Canada, France, South Korea, the United States, and Egypt were the research locations with more than ten orthopedic-related publications by KSA-affiliated orthopedic authors. Among studies conducted in KSA, authors from 23 other countries collaborated, and the top collaborators were authors working in Canada and France. The details are provided in Supplementary File 1.

Institutional characteristics

Among the institutes conducting the research, we identified 84 unique institutional entries from KSA and 86 from outside KSA. The distribution of the top ten research institutes is shown in Figure 3.

Research quality and themes

We identified 752 (71.8%) original articles, 235 (22.4%) case reports, and 51 (4.9%) review articles. These articles comprised 66 (6.97%) basic science studies and 873 (83.3%) clinical studies. Clinical studies were dominated by cross-sectional studies, case series, and case reports (Figure 4).

The level of evidence of the clinical studies was primarily level IV (Figure 5a). However, an increasing number of articles was found to contribute all levels of evidence in recent years (Figure 5b).

Information regarding the departments in which the studies were conducted was available for 1020 articles. Among the non-orthopedic specialties conducting orthopedic or related research with KSA-affiliated orthopedic coauthors, physiotherapy/rehabilitation and medicine were the major specialties (Figure 6a). Among orthopedic subspecialties, most articles pertained to general topics, the spine, and pediatric orthopedics (Figure 6b).

Author characteristics

The identified articles were contributed by 3009 authors with 5668 occurrences. The roles of authors with

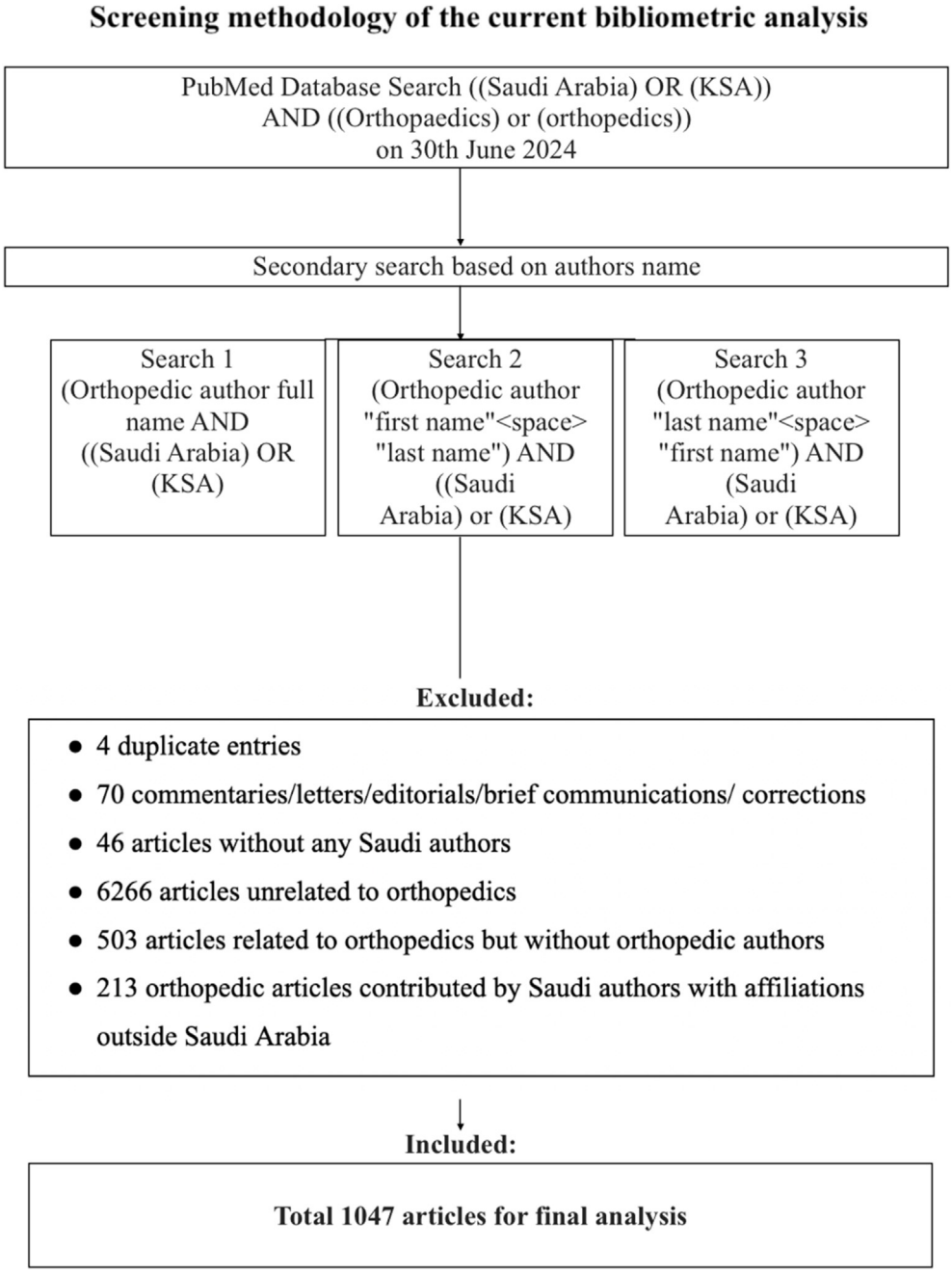

Figure 1: Screening method of the current bibliometric analysis.

affiliations in KSA among the published articles are shown in Table 1. Overall, 75% of articles had KSA-affiliated orthopedic authors with first or corresponding authorship, or both.

Journal characteristics

The eligible articles were published in 303 journals. The distribution of the orthopedic articles across journals is shown in Figure 7a. Impact factors were available for 165 listed journals, and the mean impact factor was 3.04 (range 0.4−51.1). A total of 277 journals had h-index information, and the mean h-index was 59.2 (range 1−367). Quartile information was available for 259 of 303 journals, accounting for 871 articles. The quartile distribution of these articles is shown in Figure 7b. Regarding journal subject area, 41.4% of the articles were published in orthopedic journals, and 40.6% of the articles were published in multidisciplinary journals. Very few articles were published in journals covering other subject areas (Figure 8a). Subgroup analysis of publications from orthopedic specific journals revealed that most articles were published in broad orthopedic coverage journals or those related to general orthopedics. Moreover, most published articles were in the spine, orthopedic trauma, and pediatric orthopedics specialties, in that order (Figure 8b).

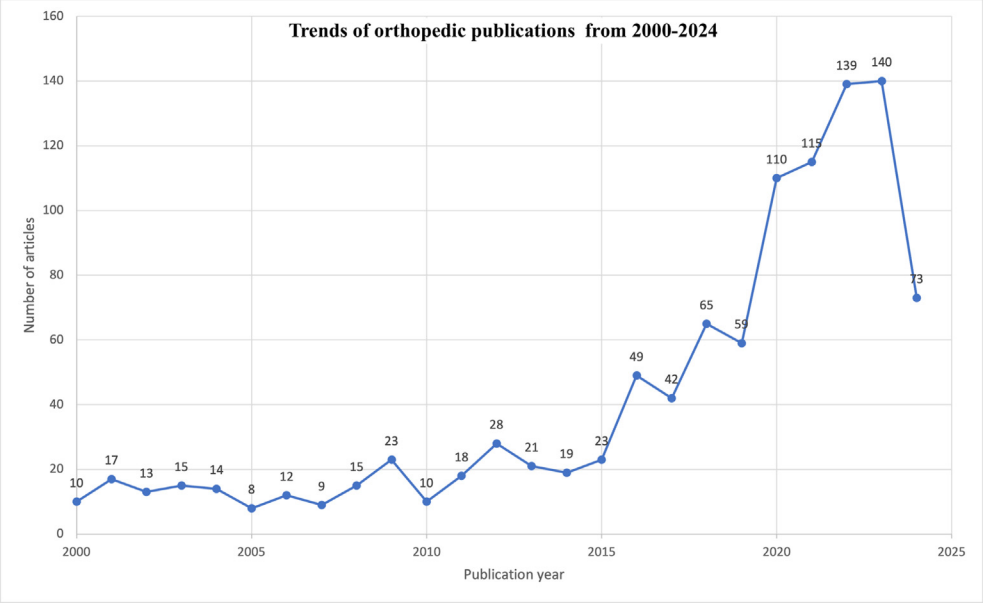

Figure 2: Trends in orthopedic publications by KSA-affiliated orthopedic authors from 2000 to 2024.

Citation trends

The eligible articles had 4337 citations, according to the PubMed database, with a mean number of citations of 4.14 per article (range 0–79). Higher total citations were observed for articles published in recent years (Table 2). The recent decrease was probably due to the recency of publications, given that some time is necessary for articles to be read and subsequently cited in publications. Moreover, we observed an upward trend in the citations per year for recently published articles (Table 2). The cumulative citations by orthopedic subspecialty are shown in Table 2. Citations in general orthopedics, spine, pediatric orthopedics, and arthroplasty clearly dominated. Table 3 shows the top ten cited orthopedic articles with orthopedic authors in KSA.

Discussion

Our findings suggested that orthopedic research in KSA has been limited but is trending upward. Our comprehensive search strategy used a widely recognized medical database (PubMed) and various analyses to provide valuable insights

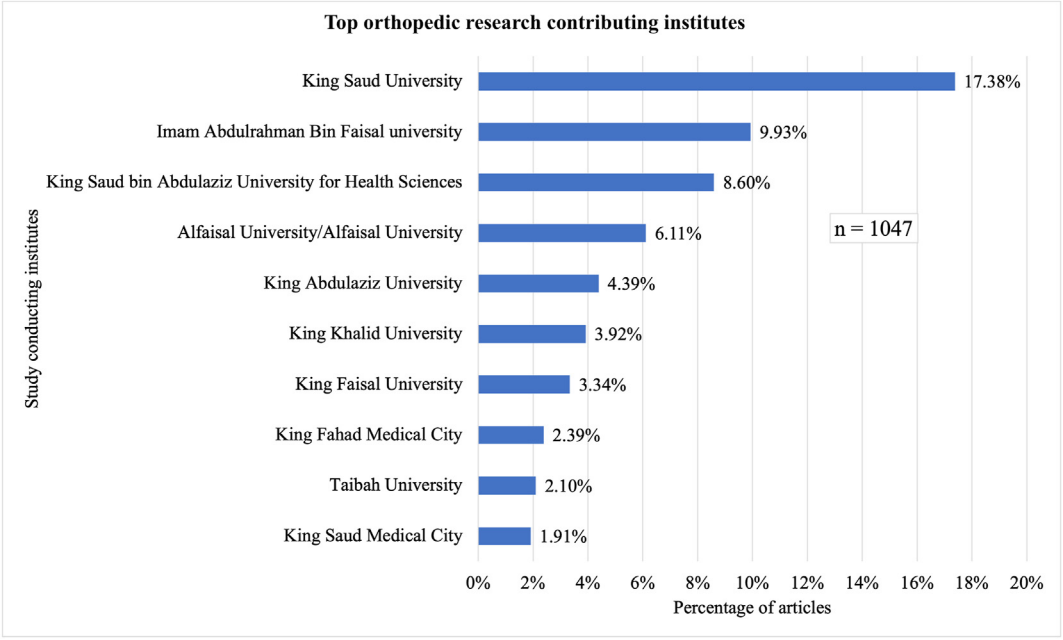

Figure 3: Top ten research institutes with orthopedic research involving KSA-affiliated orthopedic authors.

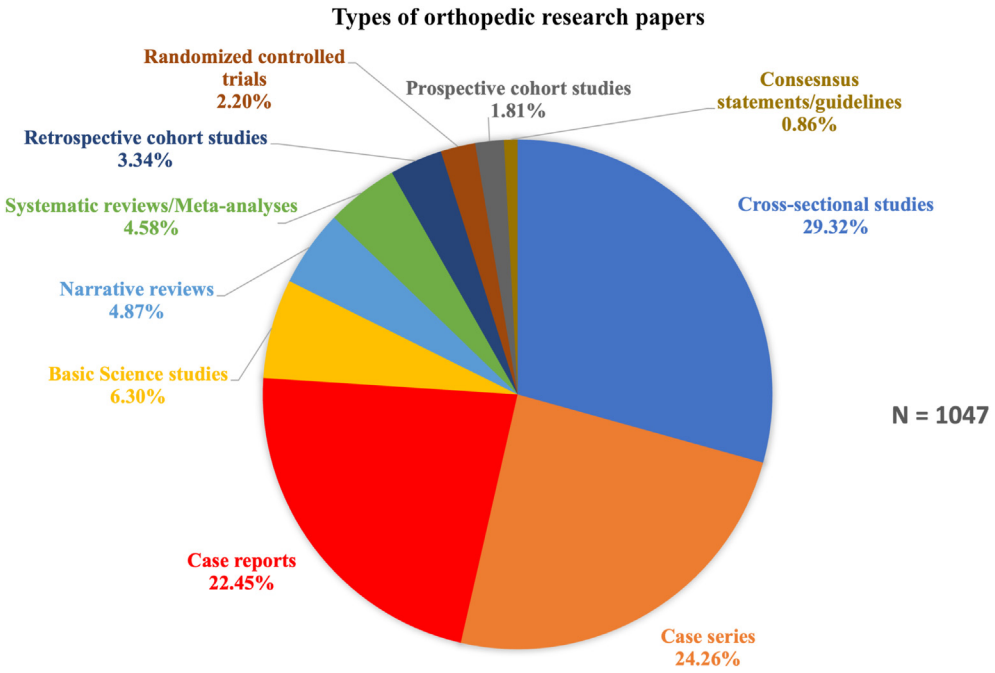

Figure 4: Types of orthopedic research articles by KSA-affiliated orthopedic authors.

into orthopedic research productivity in KSA. The PubMed index is a recognized database and the most widely accessible biomedical resources globally. Most authorsprefer to publish in PubMed-indexed journals to be able to reach a larger audience of health professionals and medical librarians.[24] The database offers a wide range of information, thus aiding in comprehensive analysis, as evidenced by our findings.[24] Non-orthopedic articles, which were excluded during screening, composed most of the search results, possibly because the keyword-based search tended to overestimate the number of articles, on the basis of the occurrence of the searched keywords in the title, abstract, or full text of the screened articles, and because of the lack of specialty-specific categories in the search options. Although the resultant search volume was high, our strategy decreased the chances of missing relevant articles. Our secondary search for articles that were potentially missed because of the lack of the "orthopedic" keyword on the PubMed record further added articles on the basis of author names and Saudi Arabian affiliations.

We observed a tremendous improvement in orthopedic research publications and a healthy growth rate in recent years (Figure 2). Another favorable finding was that research was not restricted to KSA alone but included collaborations from several high-output countries, such as the United States, Canada, and France. Moreover, the collaborations were bidirectional, involving research conducted either in KSA or in other nations. Valuable collaborations with neighboring countries were observed. Egypt was the top collaborating nation in the Middle East.

Institutional contributions reflect the high productivity of top universities in KSA. King Saud University dominated as both a primary research location and a top university collaborating with other nations. Other major contributing institutes with more than 5% of the research publications each were Imam Abdulrahman Bin Faisal University, King Saud bin Abdulaziz University for Health Sciences, and Alfasial University/King Faisal Specialist Hospital and Research Center. This pattern probably reflects the substantial resource availability and research opportunities available at these top contributing institutes. The availability of multiple allied specialties and a variety of academic courses at these institutes contributes to a research-supportive atmosphere. Moreover, medical personnel with various levels of education and expertise are available personnel for conducting research activities.

The diversity of non-orthopedic subspecialties conducting orthopedic-related research indicated that advanced research is being conducted in collaboration with orthopedic authors. Along with collaborations in major specialties, such as rehabilitation, medicine, general surgery, and neurosurgery, we observed evidence of advanced research in genetics, stem cell research, and laboratory sciences. The orthopedic subspecialty distribution indicated notable contributions from the spine, pediatric orthopedics, arthroplasty, adult trauma, sports, and oncology fields, thereby suggesting a balanced clinical research output among subspecialties. However, concerningly, very few studies (1.53%) were related to orthopedic training and education. The spine subspecialty (18.91%) had the most articles, and a similar proportion of articles were published in general topics in orthopedics, which might cover multiple subspecialties. These findings suggested that spine-related research is progressing satisfactorily, but also indicated a need for additional contributions from several lagging subspecialties, including foot and ankle, orthopedic training and education, and deformity, which represented less than 5% of the identified articles. This distribution might not reflect the clinical work being performed in various subspecialties but instead might reflect the research interests in the different subspecialties. In addition,

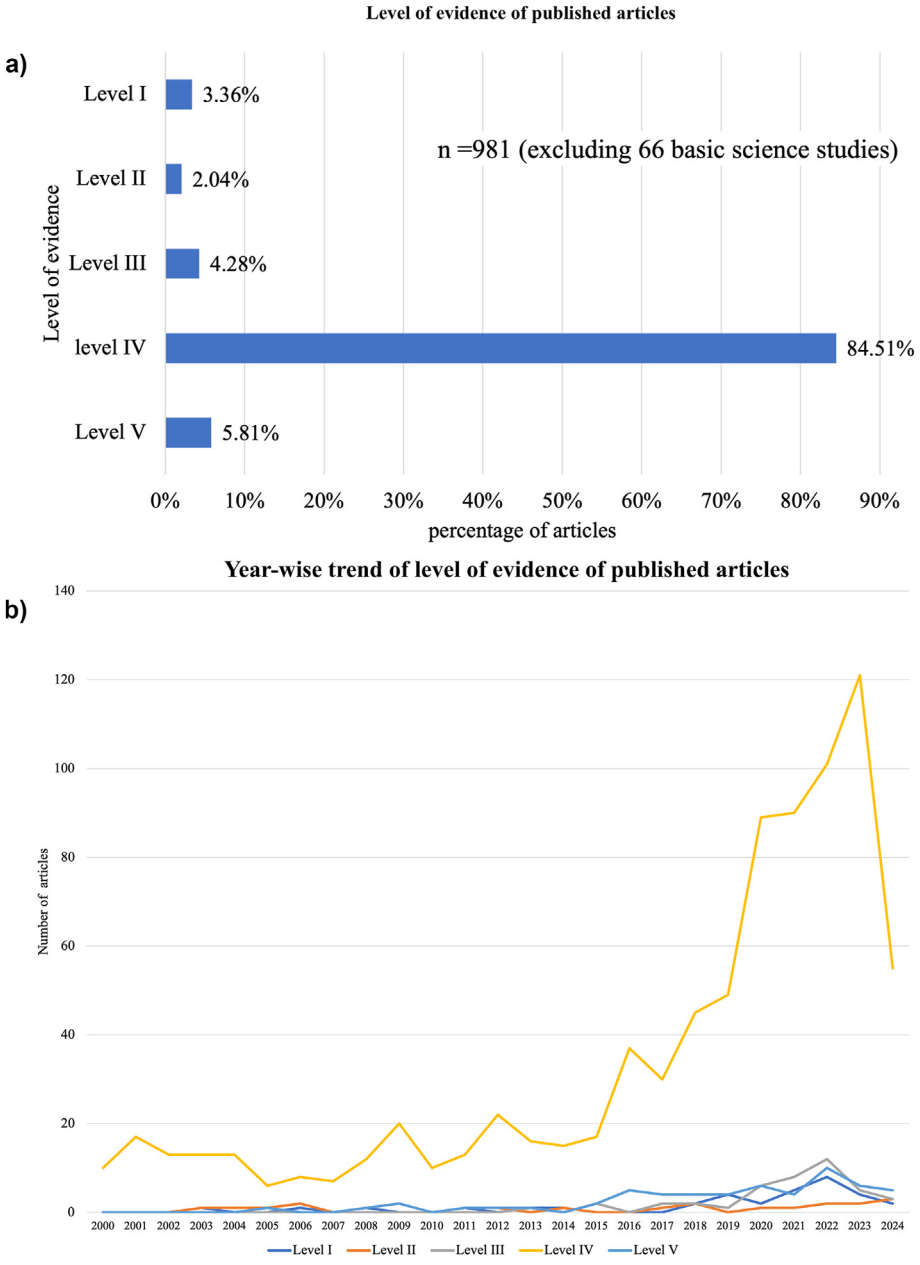

Figure 5: a) Level of evidence of orthopedic clinical articles by KSA-affiliated orthopedic authors. b) Distribution of articles' levels of evidence by year.

the more limited number of available foot and ankle surgeons than spine surgeons in KSA might have been a contributing factor.

A similar trend was reflected by the journals' subject areas. Whereas most published research was published in orthopedic specific journals, a comparable number of articles were published in multidisciplinary journals covering multiple subject areas. The reason for publications in multidisciplinary journals might have been related to the involvement of other non-orthopedic subspecialties in research or topics covered in general orthopedics. Furthermore, authors' preferences may guide the selection of multidisciplinary journals. Notably, general orthopedic and spine related journals had among the highest number of articles—a trend similar to the subspecialty distribution of orthopedic articles.

Furthermore, the research output had limited research quality: the level of evidence was primarily level 4 (84.51%). Further analysis suggested that cross-sectional studies, case series, and case reports dominated the research output. The trends by year shown in Figure 5b suggested an improvement in the level of evidence in recent years. However, very few articles were level I and II studies. This aspect might require improvement in the future, given that a higher level of evidence results in more meaningful changes in clinical practice.

Authorship alone might not have reflected the substantial contributions of authors with affiliations in KSA, in studies in which the roles of the first and corresponding authors were unknown. The International Committee of Medical Journal Editors (ICMJE) recommends that authorship be based on

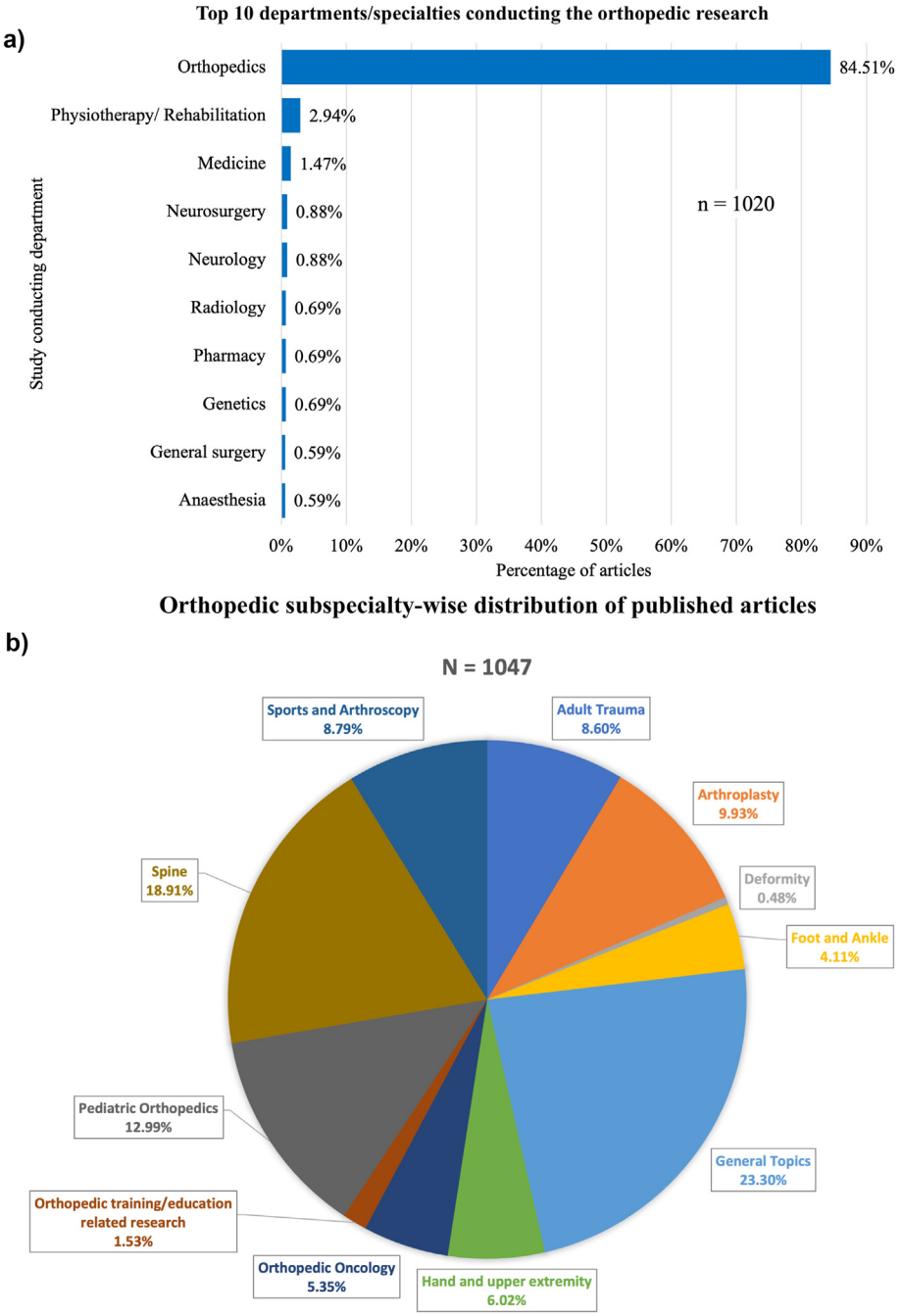

Figure 6: a) Distribution of the top ten departments conducting orthopedic research involving orthopedic authors in KSA. b) Overall distribution of orthopedic articles by subspecialty.

substantial contributions, drafting, final approval, and agreement among all authors.[25] Thus, the first authors should have contributed most to the research. The corresponding author has additional responsibilities related to documentation and records, in addition to authorship. The corresponding author should be available during submission, the peer-review process, and after publication to respond to queries related to the research.[25] We therefore investigated these aspects and found satisfactory results: authors with affiliations in KSA dominated these authorship roles in nearly three-quarters of the articles.

Similarly to the trend toward higher research output, the research content has improved in recent years: the overall citations and annual citations of recent articles were markedly higher than observed in the past several years. The preferred journal distribution suggested that *Cureus* and *Saudi Medical Journal* published the most relevant articles. However, the articles were published in a wide range of journals with impact factors as high as 41.6 and h-index values as high as 367.

Few studies on orthopedics research productivity in different countries have been published to date.[26–28] Those

Table 1: Roles of Saudi orthopedic authors in the published articles.

Role of Saudi orthopedic author	Number of articles
First and corresponding author	673 (64.28%)
Other author	274 (26.17%)
First author	62 (5.92%)
Corresponding author	38 (3.63%)

studies have investigated scholarly publication trends by using bibliometric methods. Departmental productivity has been shown to correlate with funding and leadership productivity. Funding availability has also been associated with greater research output.[26–32] The improved health and education expenditures in KSA with Vision 2030 reforms might potentially have contributed to the recent growth in orthopedic research.[5] In general, orthopedic surgery has made substantial progress, including several recent advances in orthopedic subspecialties.[33–39] However, the published evidence suggests deficient orthopedic research output in many Arab countries.[2,3,7,40] The reasons may be multifactorial, including poor research infrastructure, inadequate hospital documentation, limited technological material resources, limited research grants, and limited research time because of a high number of patients per physician.[2,3,40] However, our analysis did not address these issues. In KSA, the improved research productivity suggested that the issues have been addressed to some extent, but further efforts are needed to improve the research output. In addition, the improved research productivity might be attributable to the recent increase in orthopedic

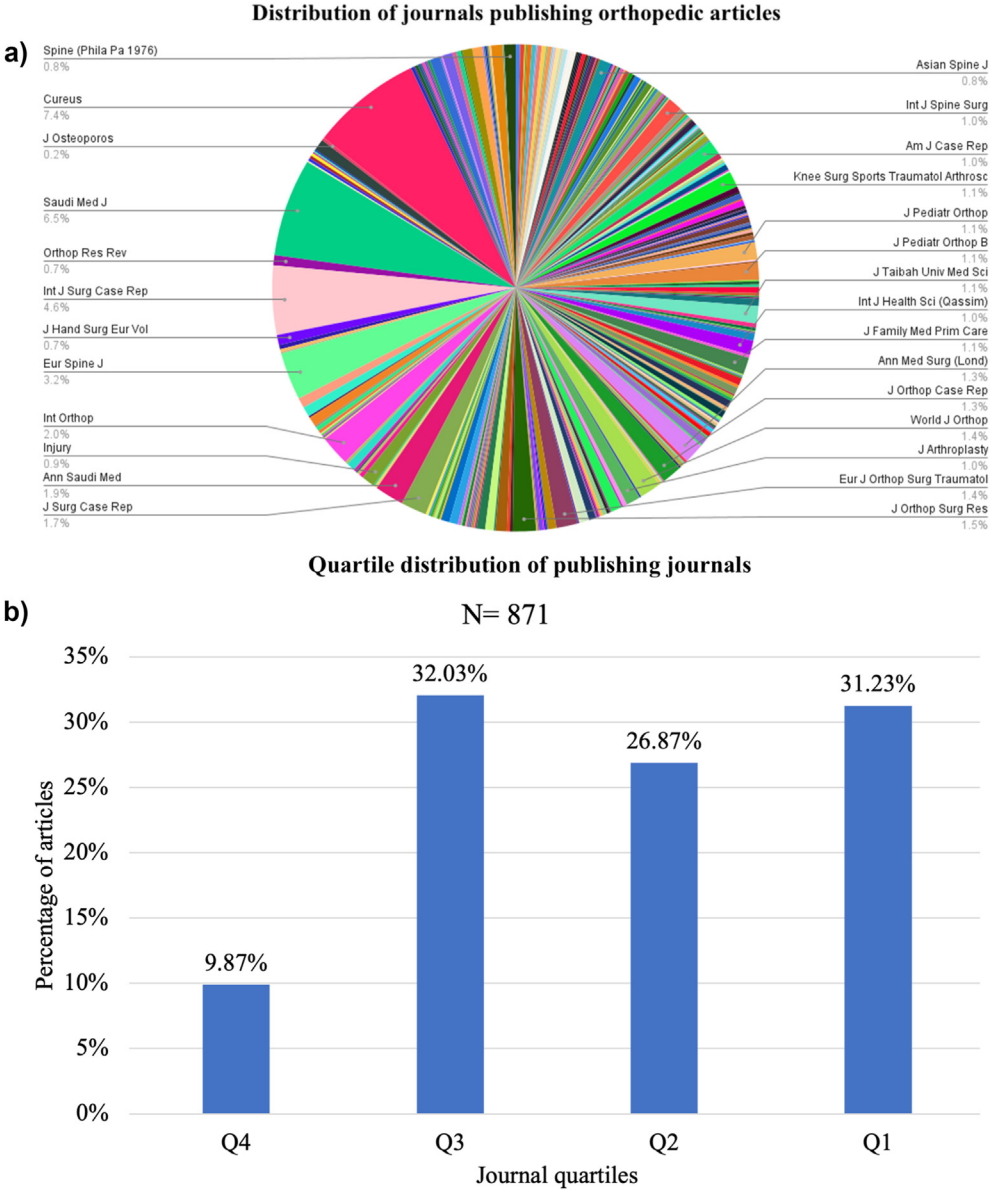

Figure 7: a) Distribution of articles by KSA-affiliated orthopedic authors across journals. b) Journal quartile distribution of articles by KSA-affiliated orthopedic authors.

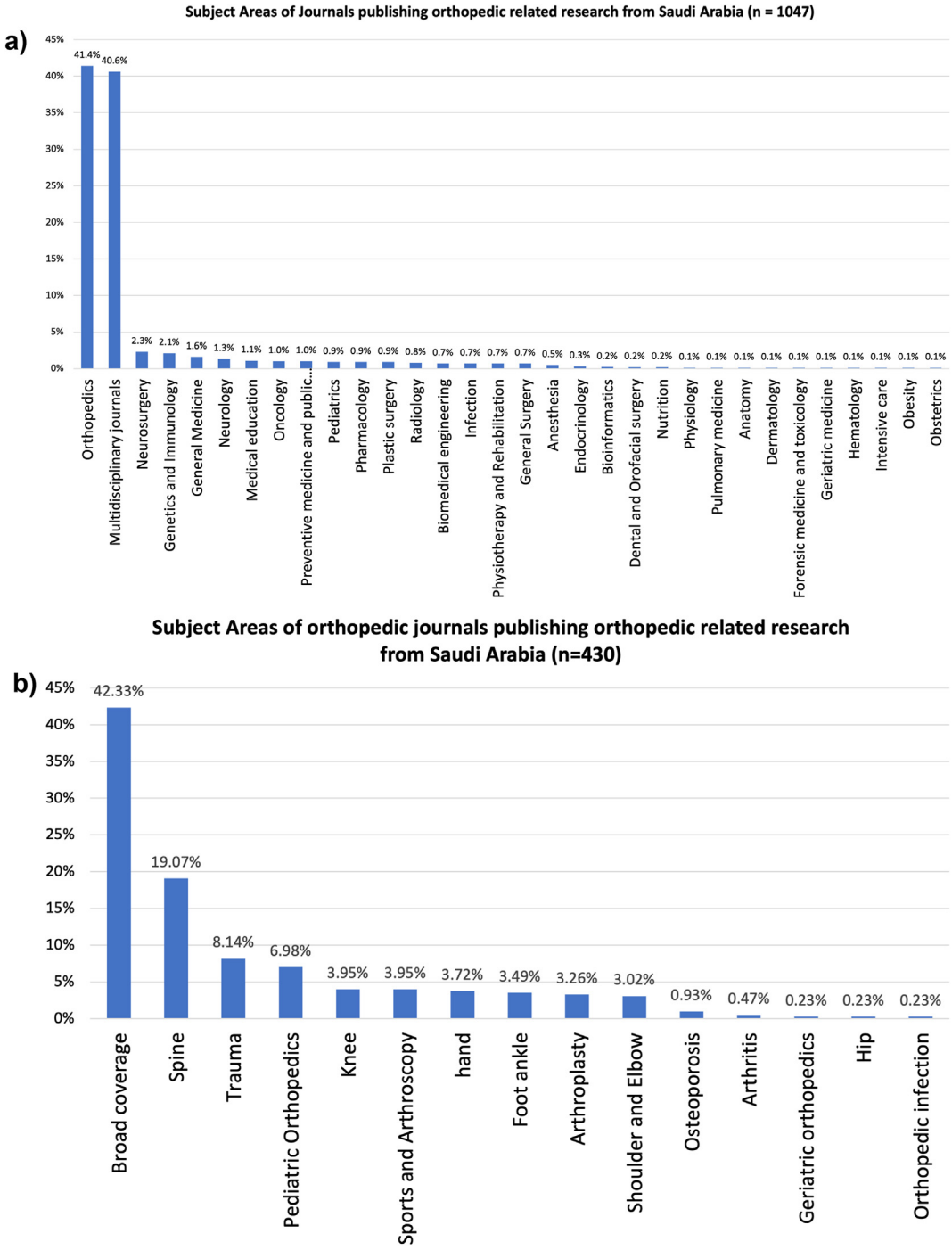

Figure 8: a) Subject areas of journals publishing eligible orthopedic-related articles by KSA-affiliated orthopedic authors. b) Subgrouping of subject areas of orthopedic journals publishing eligible orthopedic-related articles by KSA-affiliated orthopedic authors.

surgeons from KSA, who returned after training abroad and have gained experience in research, as evidenced by the observed international collaborations (Supplementary File 1). Other potential factors contributing to the improved research productivity might be related to increased numbers of orthopedic surgeons; orthopedic training programs; and implementation of strategies encouraging research in medical schools and mandatory research during residency training.

A previous study on global research productivity ranked KSA 45th in orthopedic research contributions.[27] However, the research articles analyzed in that study were from a small cross-sectional period between 2010 and 2014. The research growth curve in our analysis suggested steep growth after 2014 (Figure 2), thus suggesting that the ranking order might have improved in recent years.[27] The recent research growth surge correlates well with the better allocation of GDP funds

Table 2: Citation information for the published articles.

Citations by year (year: citations)	Cumulative citations since the publication year (publication year: citations per year)	Orthopedic subspecialty citations (total: 4337)
2000: 67	2000: 2.79	General orthopedics: 1443
2001: 95	2001: 4.13	Spine: 847
2002: 105	2002: 4.77	Pediatric orthopedics: 529
2003: 88	2003: 4.19	Arthroplasty: 383
2004: 73	2004: 3.65	Sports and arthroscopy: 329
2005: 118	2005: 6.21	Adult trauma: 268
2006: 100	2006: 5.56	Orthopedic oncology: 202
2007: 142	2007: 8.35	Foot and ankle: 136
2008: 141	2008: 8.81	Hand and upper limb: 113
2009: 180	2009: 12.00	Medical education: 55
2010: 20	2010: 1.43	Deformity: 32
2011: 135	2011: 10.38	
2012: 140	2012: 11.67	
2013: 174	2013: 15.82	
2014: 178	2014: 17.80	
2015: 180	2015: 20.00	
2016: 465	2016: 58.13	
2017: 217	2017: 31.00	
2018: 479	2018: 79.83	
2019: 316	2019: 63.20	
2020: 379	2020: 94.75	
2021: 254	2021: 84.67	
2022: 215	2022 107.50	
2023: 73	2023 73.00	
2024: 3		

toward healthcare (source: World Bank). The health sector's GDP share increased from 4.21% in 2000 to 5.9% in 2021. A similar trend in GDP allocation toward research and development funds has been observed in recent years (source: World Bank). Whereas before 2010, the GDP allocation to research and development was less than 0.1%, this percentage increased more than fourfold after 2010. Additionally, evidence of expansion in the medical sector has been observed with the launch of several new medical institutes in 2008 and thereafter.[41,42] These factors provide a research-promoting environment and thus are likely to contribute to research productivity. The research growth trend in orthopedics is similar to that in overall research productivity, as reported by Al-Marzouqi et al., who have observed steep growth curve in recent years.[43] Compared with other Gulf countries, KSA has contributed the highest number of research publications to date,[43] and has shown very promising growth trends.

International collaborations reflect research contributions from developed nations with advanced orthopedic technologies and intensive research programs. Although international collaborations are helpful in research productivity and bring new treatment modalities to the health sector, concerns have been raised that Saudi Arabian authors trained by international surgeons might contribute to major research output.[44] To avoid this confounding factor, we excluded articles in which Saudi Arabian authors did not have a primary affiliation in KSA, to restrict the analysis to research conducted primarily in KSA. The primary affiliation reflects the current workplace of the authors. We identified 213 orthopedic or related articles in which Saudi Arabian authors had primary affiliations outside KSA (Figure 1). Importantly, authors from KSA who have temporarily worked in other countries must be careful in specifying their primary affiliation. Such young orthopedic surgeons might potentially be unaware of the importance of correctly specifying their Saudi Arabian affiliations; this aspect might have resulted in many missing articles. The institute and country specified in the primary affiliation are considered to have contributed to the published article.

Although evidence regarding orthopedic research productivity in KSA or neighboring countries has been limited, such analyses on overall medical research output have suggested that Turkey leads the scholarly output (288,186 articles) in the Middle East and is closely followed by Iran (190,369 articles) and then KSA (69,214).[45] However, the contributions of individual subjects to medical research may vary. Israel has 53.82% of its scholarly output published in high-quality Q1 journals. Similarly, Qatar (45.73%), Djibouti (44.09%), Cyprus (41.48%), and KSA (41%) have large proportions of scholarly output published in top-tier Q1 journals, thus providing a promising research indicator. Although medical research still dominates other research, research based on medical subdivisions is lacking. Subject-specific evidence has been investigated for some specialties. For surgery-related research in KSA in a similar timeframe, nearly 4000 articles have been found.[46] An increasing trend in surgery-related research in Arab countries has been reported. Alhibshi et al.[47] have investigated research productivity in a short timeframe from 2013 to 2018, and have found that Engineering Sciences dominated research in KSA, and was followed by medicine and chemistry. Imran et al.,[46] in an investigation of research productivity in Arab countries, have found that only 8.3% of articles were in the orthopedics field. Khalifa et al.[3] have found that in the *Journal of Arthroplasty*, a major orthopedic journal, only 1.8% of articles are from Middle Eastern countries, primarily Israel and Turkey. This finding might be attributable to the increasing number of educational institutes, the provision of greater financial support for research, and easier communication and cooperation with international research teams. Thus, the evidence suggests that an orthopedic component of research productivity has seldom been touched and needs to be investigated to understand its current stance.

Our examination of orthopedic research publications from KSA from 2020 onward identified 577 articles—a number much higher than the 470 articles published in the two decades between 2001 and 2019 (Figure 2). Concerns have been raised regarding the scarcity of publications from KSA in top-quartile journals.[2,3] However, we observed contradictory findings, at least for the orthopedic specialty: among the articles with quartile information available, 31.23% were published in Q1 journals, and an additional 26.87% were published in Q2 journals (Figure 7b). The analysis until 2018 and the use of a single journal database in the previous study by Khalifa et al.[3] might explain the differences in findings between studies. Our current findings suggested substantial contributions of authors with affiliations in KSA to the top-quartile journals.

Table 3: Top ten most cited orthopedic articles by orthopedic authors in KSA.

S. No.	Study title	Journal	Authors	Study department	Study country	Publication year	Citations
1	Calcium metabolism and oxidative stress in bone fractures: role of antioxidants	Curr Drug Metab	Sheweita and Khoshhal[14]	Biochemistry	KSA	2007	79
2	Vitamin D deficiency in Saudi Arabians: a reality or simply hype: a meta-analysis	J Family Community Med	Al-Alyani et al.[15]	Orthopedics	KSA	2018	55
3	Defining an international standard set of outcome measures for patients with hip or knee osteoarthritis: consensus of the International Consortium for Health Outcomes Measurement Hip and Knee Osteoarthritis Working Group	Arthritis Care Res	Rolfson et al.[16]	Orthopedics	Sweden	2016	50
4	Global tilt: a single parameter incorporating spinal and pelvic sagittal parameters and least affected by patient positioning	Eur Spine J	Obeid et al.[17]	Orthopedics	France	2016	50
5	Autograft soaking in vancomycin reduces the risk of infection after anterior cruciate ligament reconstruction	Knee Surg Sports Traumatol Arthrosc	Pérez-Prieto et al.[18]	Orthopedics	Spain	2016	48
6	Expanding the clinical and genetic heterogeneity of hereditary disorders of connective tissue	Hum Genet	Alazami et al.[19]	Genetics	KSA	2016	47
7	Prevalence of surgical site infection in orthopedic surgery: a 5-year analysis	Int Surg	Al-Mulhim et al.[20]	Orthopedics	KSA	2014	45
8	Classification of coronal imbalance in adult scoliosis and spine deformity: a treatment-oriented guideline	Eur Spine J	Obeid et al.[21]	Orthopedics	France	2019	45
9	Graft tears after arthroscopic superior capsule reconstruction (ASCR): pattern of failure and its correlation with clinical outcome	Arch Orthop Trauma Surg	Lim et al.[22]	Orthopedics	South Korea	2019	44
10	Vitamin D levels in healthy men in eastern KSA	Ann Saudi Med	Sadat-Ali et al.[23]	Orthopedics	KSA	2009	43

The orthopedic specialties often require support from technology and other non-orthopedic fields to achieve better patient care. The publications from several non-orthopedic specialties indicated that such a process has already been occurring in research from KSA. Factors to further strengthen and improve KSA's research output may involve better channelization of medical workforce, with dedicated orthopedic research units given the responsibility of conducting research. Moreover, improved policy designs, hassle-free research clearance processes, and incentives may also help increase research interest among orthopedists.[48,49] Research is an important criterion for promoting faculty members in academic institutes. Efforts should be made to attract students, residents, and other orthopedic staff to participate in the research process. Additionally, the provision of mandatory research workshops would also aid in understanding of the research process.[50] Orthopedics is a busy clinical specialty with clinical, professional, and academic burdens; these factors might limit research participation. Authors active in orthopedic research might provide valuable input to encourage budding orthopedists' research participation. The top universities with high research output are among the largest in KSA, and include several medical schools with many qualified surgeons and teaching hospitals. These universities are also among the oldest in KSA and are well resourced.

In our analysis of citation trends, research growth was evident. However, the citation volume was limited and did not appear to compete with citations of orthopedic research from advanced nations such as the United States.[51] The top ten cited articles with Saudi Arabian orthopedic authors were in general orthopedics, pediatric orthopedics, sports, and the spine.[14–23] The articles covered diverse themes, including osteoporosis and bone metabolism, fractures, osteoarthritis, the genetic basis of orthopedic disorders, and scoliosis. The publications included two non-orthopedic specialties—biochemistry and genetics—involving collaborative research with orthopedic authors in KSA. Five of the ten top-cited articles related to research were conducted in non-Saudi Arabian nations: two in France, and one each in Korea, Spain, and Sweden. This observation reflects the research interests in osteoporosis and bone metabolism among the cited articles. Unfortunately, all orthopedic research articles reporting studies conducted in KSA-affiliated orthopedic departments had citation counts below 100, according to the PubMed database.

Factors such as journal impact factor, journal quartile, subject, and author profile potentially influence article citations.[52] Although the low citation rate might have been due to the relatively low level of evidence in most articles, the effects of the recent surge in research are difficult to comment on, given that further time may be necessary for

citations to occur. Given the presence of articles from well-recognized, high-impact orthopedic journals, increased citation counts are anticipated in the future.

No prior dedicated bibliometric analysis has examined orthopedic research productivity in KSA, according to a large database. The strengths of the current analysis include the long cross-sectional period of analysis from the year 2000 onward, from an era of limited productivity to the recent era of high research growth, thus aiding in the clear demarcation of current favorable research growth trends. In addition, a major database (PubMed) that has been widely used in medical research was searched.[24] Our analysis highlights several aspects of orthopedic research in KSA, ranging from those that are satisfactory to those that require attention to be improved. Our findings may be used to formulate better research plans, strategies, and resource utilization.

Limitations

The current study has several limitations. First, the analysis used one database for retrieving records of Saudi Arabian orthopedic research from January 2000 to June 2024. However, the database (PubMed) is a well-recognized index that should enable reasonable inferences, as discussed above. Second, for studies lacking clear information regarding the study institute, we assumed institutional locations according to information such as ethical clearance, acknowledgments, funding, and addresses. However, confirming the locations for such research articles would have been impractical. Third, although we attempted to include as many research productivity-related variables as possible, scope exists for additional analyses, which may require new methods. However, additional analyses might render the results lengthy and less relevant to the purpose of the current study. Fourth, journals' impact factors, h-index values, and quartile information vary with time. These parameters might have changed from when the articles were published to the time of the current analysis. However, standardizing the analysis timeframe is acceptable for quality assessment. Fifth, potential concerns are related to changes in institutional names and different authors using different names for the same institutes. Several institutes' names were changed in KSA during the cross-sectional study period. Although we attempted to screen for all such changes by searching institutional websites, a minor number might have been missed. Finally, the current analysis was primarily descriptive, and was aimed at providing an overview of Saudi Arabian orthopedic research output. Nonetheless, this study provides valuable information regarding the current status of KSA-based orthopedic research, such as research quality and relevance, which can be predicted through citations, as well as research hotspots and themes in KSA. Additional dedicated research is needed to understand the factors affecting orthopedic research productivity in KSA.

Conclusion

Our bibliometric analysis suggested that orthopedic research productivity from KSA has been limited; however, KSA-affiliated orthopedic authors showed emerging roles at both the national and international levels, particularly in recent years. We observed ample evidence of research growth, and cross-specialty and international collaborations in orthopedic research. However, the research productivity was dominated by several institutes in KSA, with just two institutes contributing to nearly 30% of the articles. In addition, although authors with affiliations in KSA have published in top orthopedic journals, a need exists for improvement in the quality of clinical research, given that most published evidence was of level IV. Further efforts should be made to strengthen research opportunities and encourage research participation among Saudi Arabian medical institutes and orthopedic authors.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflict of interest

The authors have no conflict of interest to declare.

Authors contributions

AZA and NAT conceived and designed the study, conducted research, provided research materials, and collected and organized data. KIK analyzed and interpreted data. AZA wrote the initial and final drafts of the article, and provided logistic support. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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Appendix A. Supplementary data

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