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Pose Estimation in Yoga: A Bibliometric Exploration of Technological Advancements in Sports Sciences

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ABSTRACT

The integration of technology into yoga practice has seen significant advancements in recent years, particularly in the realm of pose estimation. Pose estimation refers to the computational process of determining the configuration of a person's body in a given posture, becoming a crucial tool for enhancing physical activity monitoring and improving technique in various sports and fitness applications, including yoga. Accurate analysis of yoga poses offers insights into body alignment, posture correction, and performance improvement, which are essential for efficacy and injury prevention. Traditional instruction relies on visual observation and verbal cues; however, the advent of artificial intelligence (AI) and computer vision technologies has enabled automated systems to assist in posture analysis, thereby enhancing self-guided practice. This paper presents a bibliometric exploration of pose estimation in yoga, highlighting technological advancements and key research trends. Utilizing the Scopus database, a keyword-based search yielded 106 results, refined to 16 high-quality articles through specific inclusion and exclusion criteria. Analysis reveals a steady publication rate, a broad range of interdisciplinary sources, and the collaborative nature of research in this field, with India and the USA being prominent contributors. Despite significant advancements, gaps remain in recognizing nuanced postures and evaluating the long-term outcomes of these technologies. This study underscores the need for ongoing research to refine pose estimation techniques and explore their practical applications effectively, ultimately enhancing the experience and effectiveness of yoga practice.

Keywords: *Artificial intelligence, Computer vision, deep learning, Sports science, yoga practice.*

1. INTRODUCTION

The integration of technology into yoga practice has seen significant advancements in recent years, particularly in the realm of pose estimation. Pose estimation, which refers to the computational process of determining the configuration of a person's body in a given posture, has become a crucial tool for enhancing physical activity monitoring, improving technique, and providing real-time feedback in various sports and fitness applications, including yoga. The ability to accurately estimate and analyze yoga poses has opened new opportunities for practitioners, instructors, and researchers alike, offering insights into body alignment, posture correction, and performance improvement.

In yoga, precise alignment of the body is fundamental to both the efficacy of the practice and injury prevention. Traditional yoga instruction relies on visual observation and verbal cues to correct poses. However, with the advent of artificial intelligence (AI) and computer vision technologies, automated systems can now assist in analyzing postures with high accuracy, reducing the reliance on human intervention and enhancing self-guided practice. Pose estimation models, utilizing techniques like convolutional neural networks (CNNs) and recurrent neural networks (RNNs) [1, 2], track body landmarks such as joints and limbs, enabling real-time evaluation of the poses being performed. Some recent advancement include the development of 2D and 3D pose estimation algorithms that provide a more detailed analysis of body movement in complex postures.

Bibliometric analysis, a method that uses quantitative techniques to assess the scholarly impact of research within a specific domain, has become an essential tool in mapping the development and trends in technological advancements. This approach offers insights into the progression of research fields, identifying key contributions, trends, and collaborative networks among researchers. By analyzing the growth of literature and identifying influential studies, bibliometric analysis helps researchers understand the current state of technology adoption in yoga and its potential future applications. Additionally, a bibliometric study can reveal emerging themes in yoga-related pose estimation, such as the increasing interest in wearable technology for motion tracking, augmented reality (AR) systems for real-time corrections, and AI-driven personal trainers.

This paper aims to present a bibliometric exploration of pose estimation in yoga, highlighting technological advancements and key research trends in the field [3, 4]. By assessing the citation patterns, publication volumes, and collaborative networks, this study seeks to provide a comprehensive understanding of the progress made and the future directions in this interdisciplinary area of research. Understanding these trends will offer valuable insights for both technology developers and yoga practitioners in optimizing the practice through innovation.

2. LITERATURE REVIEW

The first significant paper that used deep learning for human posture estimation was called DeepPose, and it was published in CVPR 2014. In 2014, it outperformed previous models and attained SOTA performance [5]. The model has an AlexNet backend and estimates poses holistically, meaning that when a position is reasoned holistically, it can predict certain poses even if some joints are hidden.

One of the more challenging problems in computer vision is human estimation. Finding human joints in a picture or video to create a skeletal model is its focus. It is challenging to automatically identify a person's stance in an image since it depends on a number of factors, such as B [6]. Image scale and resolution, background noise, lighting variations, clothing changes, the setting, and interactions between people and their surroundings. Exercise and fitness are two applications of human pose assessment that have captivated numerous researchers in this field.

Using the slow, dynamic, and static stretching components of exercise, sun salutation is the best exercise for creating the most stress on the respiratory and cardiovascular systems. Four rounds of the sun salute were evaluated for their effects on the metabolic and cardiorespiratory systems in order to investigate its potential as a weight loss and fitness intervention. Six Asian Indian men and women, ages 18 to 22 [7], who had been doing sun salutations for longer than two years and were in good condition, participated in this study. The Oxycon Mobile Metabolism System and a heart rate monitor were worn by the study participants to measure their oxygen consumption and heart rate throughout the four sun salutations.

3. METHODOLOGY

The bibliometric analysis was conducted using the Scopus database, chosen for its comprehensive coverage of peer-reviewed literature across multiple disciplines, including computer vision, artificial intelligence, and sports science. These fields are directly relevant to the study of pose estimation in yoga. A keyword-based search was carried out in Scopus using the terms "Pose Estimation" and "Yoga [8, 9, 10]," yielding a total of 106 results. To ensure that only high-quality and relevant studies were included, the search results were refined using filters for document type and publication stage.

To maintain the focus on original research, specific inclusion and exclusion criteria were applied. Articles, which provide detailed methodology, results, and discussions crucial for understanding advancements in pose estimation technologies, were selected. This narrowed the results to 17 articles. Additionally, only finalized publications were considered, excluding articles in press and reducing the dataset to 16 articles. Conference papers, which often report preliminary findings, were excluded, removing 85 papers. Conference reviews, book chapters, and reviews were also excluded, as they primarily summarize existing literature without contributing new empirical data. In total, two conference reviews, one book chapter, and one review were excluded, as well as one article in press.

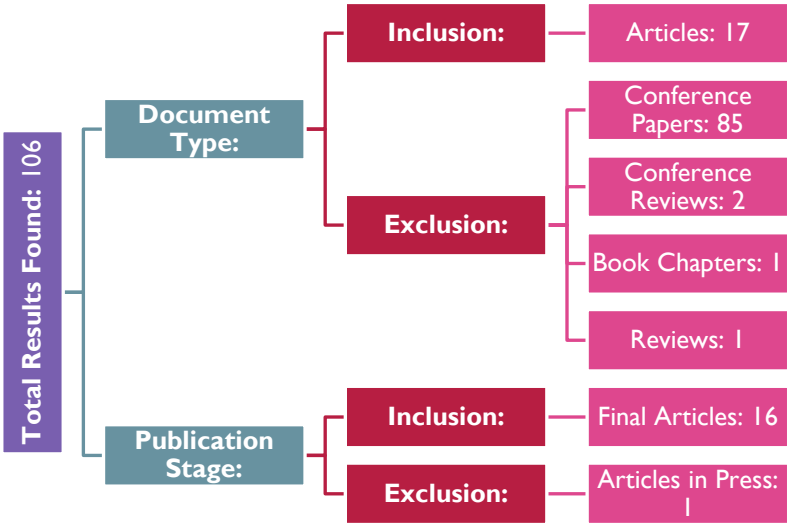

Figure 1: Systematic Data Refinement Process for Document Selection

For the 16 final articles, metadata was extracted, including title, author(s), publication year, journal, abstract, citations, keywords, and affiliations. This data formed the basis for analyzing publication trends, research impact, and collaboration patterns in the domain of yoga pose estimation [11, 12]. The collected data were then analyzed using Bibliophagy R Studio, which facilitated the exploration of publication trends and key patterns within the research field.

Figure 1 provides a visual representation of these steps in data refinement, showing the systematic approach taken to filter the most relevant documents for the study.

4. RESULTS

The bibliometric analysis on "Yoga and Pose Estimation" covers the years 2022 to 2024, highlighting a relatively recent area of research interest. The data comprises publications from 15 different sources, indicating a broad range of venues, possibly reflecting interdisciplinary interest across fields such as computer vision, artificial intelligence, health, and sports science. A total of 16 documents were analyzed, with an annual growth rate of 0%, signifying a steady publication rate during this period. On average, the documents are quite recent, with an average age of 1 year [13, 14]. Each document has been cited approximately 6.188 times, suggesting early impact and relevance for this emerging topic. Interestingly, there were no references available in the extracted dataset, which may indicate limitations in data capture or a lack of references within the documents themselves.

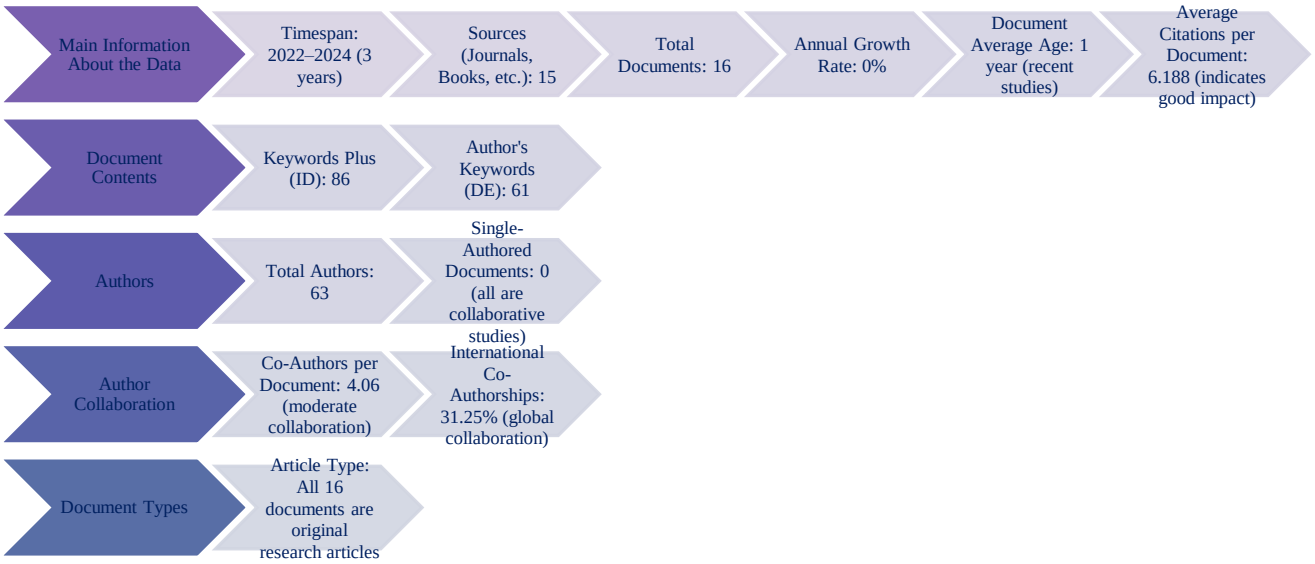

Figure 2 illustrates this main information, visually summarizing the key findings of the analysis.

The analysis also reveals 86 Keywords Plus and 61 Author's Keywords, suggesting a wide variety of terms associated with the documents and highlighting the diverse terminology used in this niche research area. With 63 different authors contributing to the 16 documents, the collaborative nature of the field is evident, as there are no single-authored documents. On average, each document has 4.06 co-authors, and approximately 31.25% of the papers involve international collaborations, indicating a global interest in pose estimation in yoga. Notably, all documents in this analysis are research articles, reflecting original empirical studies rather than reviews or conference papers.

Table 1 presents a detailed overview of the year-wise scientific production and citation metrics for the study on yoga and pose estimation.

Year	N	MeanTCperArt	MeanTCperYear	CitableYears
2022	4	16.50	5.50	3
2023	8	3.75	1.88	2
2024	4	0.75	0.75	1

Table 1 provides a year-wise breakdown of scientific production and citation metrics related to the study of yoga and pose estimation. In 2022, the year marked the highest output, with 4 articles published. These articles received an average of 16.50 citations per article (Mean TC per Art), contributing to a total mean citation of 5.50 per year (Mean TC per Year) over the three-year span. The Citable Years value of 3 indicates that these articles are still within their citable period, allowing for continued citation growth in future years. In 2023, the number of articles published increased to 8, but the average citations per article dropped to 3.75, leading to a reduced total mean citation of 1.88 per year. The Citable Years value of 2 suggests that these articles are also still within their citable period but may not have reached their full citation potential yet. In 2024, 4 articles were published, but the average citations per article decreased significantly to 0.75, resulting in a mean citation of 0.75 per year. The Citable Years value of 1 indicates that these articles are newly published and have not had enough time to accumulate citations [15], which is reflected in the lower citation rates. Overall, the data suggests that while 2022 saw a strong start in both production and citation impact, there has been a notable decline in citation metrics over the subsequent years, particularly in 2024, indicating a potential need for increased visibility or impact of the more recent studies.

Figure 3 illustrates the collaborative efforts between countries in the field of yoga and poses estimation research, showcasing a total of six distinct collaborations involving seven pairs of countries. Canada and Singapore are linked by one collaboration [16, 17], highlighting a connection between these two nations in this research area. Similarly, Egypt and Saudi Arabia show a single collaborative effort, suggesting shared research interests or projects between these countries. Notably, India emerges as a prominent contributor, engaging in collaborations with three different nations: the Czech Republic, Myanmar, and Saudi Arabia [18], each reflecting one collaborative effort. This indicates India's active role in fostering international partnerships in yoga pose estimation research. Additionally, the USA collaborates with both Canada and Singapore, further emphasizing the international nature of the research community in this field.

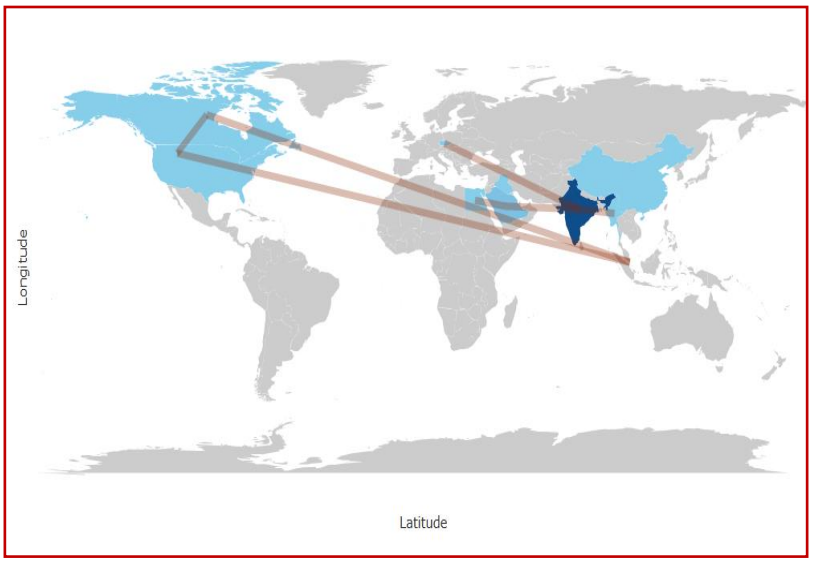

Figure 3 shows the collaborative efforts between countries

Overall, the collaboration data reveals a diverse network of international partnerships, particularly featuring India and the USA [19, 20], underscoring the global interest in yoga pose estimation research. These collaborations facilitate the exchange of ideas and resources, enhancing the overall quality and impact of research in this area.

5. DISCUSSION

The bibliometric analysis of research on yoga and pose estimation reveals a dynamic landscape marked by innovative approaches and technological advancements. Selected studies exemplify significant trends and findings in this evolving field, particularly the integration of deep learning and machine learning techniques.

The study "Yoga with Deep Learning: Linking Mind and Machine" explores how deep learning methodologies can enhance the understanding and practice of yoga, underscoring the potential for technology to improve practitioner outcomes. Similarly, "Smart Yoga Assistant: SVM-Based Real-Time Pose Detection and Correction System" demonstrates the application of Support Vector Machine (SVM) algorithms to provide real-time feedback, highlighting a practical application that addresses common challenges in maintaining correct postures during yoga practice.

Another pivotal contribution is "Region-Based Network for Yoga Pose Estimation with Discriminative Fine-Tuning Optimization," which emphasizes the importance of optimizing pose estimation models for better accuracy. This finding aligns with "Yoga Pose Estimation Using Angle-Based Feature Extraction," which presents a novel approach to identifying yoga poses based on geometric angles, further illustrating the diverse methodologies employed in this research area.

The impact of real-time video analysis is highlighted in "Recognition of Yoga Asana from Real-Time Videos Using Blaze-Pose," showcasing the effectiveness of contemporary computer vision techniques in assessing yoga postures during practice. This is complemented by studies such as "Real-Time Yoga Pose Classification with 3-D Pose Estimation Model with LSTM," which incorporate advanced deep learning architectures like Long Short-Term Memory (LSTM) networks for more robust pose classification.

The literature also identifies a gap in the recognition of nuanced yoga postures, as discussed in "Fine-Grained Sports, Yoga, and Dance Postures Recognition: A Benchmark Analysis." This benchmark study emphasizes the need for improved recognition techniques for complex postures, reinforcing the notion that further refinement in pose estimation technologies is essential for practitioners and instructors alike.

Moreover, the analysis highlights the significance of evaluating performance through comparative studies, as seen in "Ultimate Pose Estimation: A Comparative Study." This work illustrates the need to assess various pose estimation methods against one another, providing valuable insights into the effectiveness of different approaches.

This bibliometric analysis synthesizes these findings, illustrating that while significant advancements have been made in yoga pose estimation through deep learning and machine learning, there remains a need for further exploration of practical applications and long-term outcomes. It emphasizes the importance of collaborative efforts in refining these technologies and integrating them effectively into yoga practice, ensuring that they are beneficial for practitioners and instructors alike.

Finally, the results of the selected studies within this analysis reveal a promising trajectory at the intersection of yoga and technology. However, the identified gaps indicate the necessity for ongoing research that not only advances pose estimation techniques but also evaluates their practical implications in real-world yoga practice. This will ultimately enhance the overall experience and effectiveness of yoga, linking the mind and machine in a way that benefits both practitioners and researchers.

6. CONCLUSION

The integration of deep learning and machine learning techniques into yoga pose estimation has resulted in significant advancements, demonstrating a promising trajectory for both practitioners and researchers. The selected studies highlight the potential of innovative methodologies, such as SVM algorithms, LSTM networks, and angle-based feature extraction, in enhancing the understanding and practice of yoga. Additionally, real-time feedback mechanisms and optimized pose estimation models address common challenges faced by practitioners in maintaining correct postures. However, despite these advancements, gaps remain in the recognition of nuanced yoga postures and the evaluation of long-term outcomes of these technologies in real-world practice. This bibliometric analysis underscores the need for ongoing research to refine these technologies and explore their practical applications effectively.

To further this progress, researchers should focus on developing more sophisticated algorithms capable of recognizing and classifying nuanced and complex yoga postures. Conducting longitudinal studies is essential to evaluate the long-term effectiveness and practical implications of pose estimation technologies in yoga practice, helping to assess their impact on practitioner outcomes and overall experience. Encouraging collaboration between computer scientists, yoga practitioners, and sports scientists can lead to the development of user-friendly applications tailored to the needs of yoga practitioners and instructors. Additionally, technology developers should prioritize creating applications that provide real-time feedback and guidance in an intuitive manner, allowing practitioners to easily interact with the technology during their practice.

Incorporating pose estimation technologies into yoga training programs can provide valuable feedback to both instructors

and practitioners, with training sessions that focus on how to effectively use these technologies to enhance practice and performance. Engaging with the yoga community through workshops and seminars can facilitate a better understanding of the benefits and limitations of these technologies, fostering a collaborative environment for feedback and improvements. By addressing these recommendations, future research can enhance the effectiveness of yoga practice through technology, ultimately benefiting both practitioners and researchers alike.

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