Informatics and Health 2 (2025) 99–118

Contents lists available at ScienceDirect

Informatics and Health

journal homepage: www.keaipublishing.com/en/journals/informatics-and-health/

Advancing public health through artificial intelligence in physiotherapy: a bibliometric analysis

Basil Hanafi [a,*], Ahmad Hasan [b], Anas Ahmad [c], Mohammad Ali [a]

[a] Department of Computer Science, Aligarh Muslim University, Aligarh, India
[b] Department of Commerce, Aligarh Muslim University, Aligarh, India
[c] Manav Rachna International Institute of Research and Studies, Faridabad, India

ARTICLE INFO

Keywords:
Artificial Intelligence
Physiotherapy
Bibliometric analysis
Performance analysis
Science mapping

ABSTRACT

Background: This scientometric study investigates global trends and applications of artificial intelligence (AI) in physiotherapy, including rehabilitation, movement analysis, and telerehabilitation, between 2006 and 2024. The increasing applications of AI in physiotherapy may have the potential to enhance outcomes, increase operational efficiency, and bring innovative solutions. However, the rapid evolution of AI technologies and applications in physiotherapy necessitates critical examination of patterns of research and geographic differences.
Methods: The articles were published and indexed in Web of Science and Scopus, and data collection was done in July 2024. A thorough search query was employed: TITLE-ABS-KEY ("Artificial Intelligence" OR "AI") AND ("Physiotherapy" OR "Physio" OR "PT"), which yielded 377 records. Excluding 35 duplicate records and 2 non-eligible studies screened, 340 studies were included. The inclusion criteria were peer-reviewed journal articles, conference articles, and review articles in the English language with a minimum of five citations. Exclusion criteria ruled out non-peer-reviewed articles, editorials, and non-physiotherapy-related studies.
Findings: The analysis identifies a uniform rate of growth in research productivity with a steep rate of growth between 2019 and 2022 with advances in artificial intelligence technologies, such as machine learning, wearable technology, and robot rehabilitation. The major research institutions were mapped in North America, Europe, and Asia; however, significant geographic disparities exist. Bibliometric indicators, such as H-index, collaboration networks, and co-authorship analysis, were used to quantify the productivity of authors, journals, and institutions.
Interpretation: AI has shown its potential to transform physiotherapy, in particular, to maximize rehabilitation and treatment outcomes. The review does note, however, that future studies should consider ethical factors, such as data privacy, algorithmic bias, and explainability. The findings suggest the significance of exploring the long-term clinical impact of AI and interdisciplinary collaboration to address regional inequalities. Research needs to be carried out in underexplored areas, such as pediatric rehabilitation and AI-based decision-making systems, to ascertain even and effective AI integration into physiotherapy practice among populations.

1. Introduction

The intersection of Healthcare and Artificial Intelligence (AI) has been amongst the most radical advancements in the recent past that has revolutionarily changed the method of conducting medical practices and delivering patient care in the public health sector.[1] Broadly, AI in healthcare has been instrumental in areas such as diagnostic automation, robotic surgeries, personalized patient monitoring, and predictive analytics for disease outbreaks. For example, AI-driven diagnostic systems, such as those developed for the early detection of diabetic retinopathy, demonstrate the significant potential of AI integration into medical imaging and patient monitoring workflows.[2] Within this larger context lies a specific domain where AI's application presents unique challenges and transformative opportunities: physiotherapy.

Physiotherapy, in the past dominated by manual evaluation and treatment, is now about to gain immensely from AI-based developments in the field of public health. The growing field of robotic-assisted surgical procedures parallels similar advancements in AI-driven physical rehabilitation technologies such as robotic gait trainers and exoskeletons, highlighting how automation and robotics are transforming

* Correspondence to: Department of Computer Science, Aligarh Muslim University, Aligarh 202002, India.
E-mail addresses: gh2773@myamu.ac.in (B. Hanafi), gg4112@myamu.ac.in (A. Hasan).

https://doi.org/10.1016/j.infoh.2025.05.001
Received 15 March 2025; Received in revised form 13 May 2025; Accepted 20 May 2025
Available online 5 June 2025

both surgical and rehabilitative domains.[3] Unlike general healthcare, AI in physiotherapy particularly emphasizes movement analysis, rehabilitation progress tracking, remote monitoring, and individualized exercise regimens. Technologies like machine learning, deep learning, and neural networks have enabled precision in diagnosing musculoskeletal conditions, customizing therapy plans, and facilitating telerehabilitation. Technologies like machine learning, deep learning, and neural networks have enabled precision in diagnosing musculoskeletal conditions, customizing therapy plans, and facilitating telerehabilitation. Mathematical frameworks such as those based on minimal prime and semi-prime submodules have supported these advancements by enhancing the robustness and generalization capacity of AI models in clinical decision systems.[4] Such technologies have the promise of increasing the accuracy of diagnosis, tailoring treatment regimens to individual requirements, and providing individualized patient treatment that is more sensitive to specific patient needs. The use of AI in physiotherapy, from rehabilitation and analysis of human movement to remote monitoring and telerehabilitation, is a major step forward in the discipline's capacity to provide effective and efficient healthcare services in the public health sector.[5]

Artificial intelligence technologies, such as machine learning, deep learning, and neural networks, are increasingly being used to tackle intricate problems in physiotherapy.[6] Machine learning, where it can process large amounts of data and determine patterns, is especially valuable in enhancing diagnostic precision and patient outcome prediction in the public health setting. For example, AI algorithms can be trained to identify faint patterns in patient information that can be a sign of some conditions, allowing for earlier and more precise diagnoses. Deep learning, a branch of machine learning, goes one step further by applying neural networks to handle and learn from unstructured data, e.g., medical images. This has important applications for physiotherapy, where the interpretation of clinical imaging and movement data is of paramount importance.[7] The fact that AI can automate these steps not only increases accuracy but also saves precious time for healthcare practitioners, enabling them to spend more time on caring for patients within the public health sphere.

Maybe the most promising application of AI in physiotherapy is in rehabilitation. Rehabilitation is likely to require constant tracking and adjusting of therapies to achieve the best outcomes.[8] AI can assist with that process by providing feedback in real time about patient improvement so that treatment plans can be adjusted as needed. For instance, wearable technology equipped with artificial intelligence can monitor the movement of patients and supply information on how well specific exercises are working, enabling more individualized and effective rehabilitation programs within the public health sector.[9] Moreover, AI can be employed to create predictive models that determine the chances of recovery of a patient based on a number of different factors, which enables therapists to make interventions accordingly within the public health sector. Fuzzy logic models, widely applied for reliability allocation in complex healthcare systems, also demonstrate how AI-driven frameworks can enhance decision-making processes by addressing uncertainties inherent in patient rehabilitation.[10]

The emergence of telerehabilitation, led by AI, is another major breakthrough in physiotherapy.[11] Telerehabilitation enables patients to undergo therapy, from the convenience of their homes, bypassing issues like distance, mobility, and time. AI makes the experience even better by delivering customized therapy regimens that can be real-time modified according to patient improvement. In addition, AI-based platforms can mimic the presence of a therapist, leading the patient through exercises and giving feedback based on their performance. This not only makes the services of physiotherapy more available but also guarantees that patients comply with their rehabilitation regimens, something that is paramount to realizing positive outcomes in the public health field.[12]

Despite these improvements, the deployment of AI into physiotherapy is not issue-free. Of major concern among them is the ethical use of AI in health. The utilisation of AI entails the generation and processing of large volumes of patient data with concerns regarding confidentiality and data integrity in the public health sector.[13] There is also the concern of algorithmic bias and transparency. AI systems are typically perceived as "black boxes" because they are complicated, and therefore it is hard to comprehend how they come up with specific decisions. This opacity may cause distrust on the part of both patients and medical professionals. Training healthcare workers in using explainable AI tools is vital for reducing negligence and ensuring effective integration of AI into public health interventions.[14] Ethical concerns such as algorithm bias in AI and data-privacy issues are pertinent in physiotherapy, where precise movement analysis is essential. Regional variations of AI implementation also amplify the current inequalities and thus call for international efforts of equal access to AI technology. In addition, when the biased data sets are used to train the AI algorithms, they may lead to perpetuating the already entrenched disparities in healthcare due to less effective or accurate care to these populations. Thus, AI systems must be developed based on principles like transparency, fairness, accountability, and inclusiveness in the public health sector. Global ethical frameworks, such as AI4People's Five Pillars (beneficence, non-maleficence, autonomy, justice, and explicability) and the WHO's 2021 guidelines on Ethics and Governance of Artificial Intelligence for Health, strongly advocate for these principles to be embedded into healthcare AI systems. Their adoption is critical for ensuring that AI technologies in physiotherapy are trustworthy, equitable, and beneficial across different demographics and socio-economic contexts.

Besides this, the health sector is increasingly integrating artificial intelligence into its services. Thus, physiotherapy appears to be one field still not given much emphasis and largely excluded from actual applications in health, like telerehabilitation, wearable technology, and predictive analytics. Ethics and geography are not adequately represented. The AI in the health sector has developed greatly; the world market for AI is expected to be $187.95 billion by 2030. Still, some of the applications remain with a long way to go, e.g., AI-assisted rehabilitation in physiotherapy and movement analysis under the umbrella of public health.

The second is interdisciplinary collaboration. Deployment of AI into physiotherapy requires collaboration among computer scientists, clinicians, and ethicists so that AI technologies can be appropriately and ethically applied. Collaboration them is crucial in designing AI systems that are technically excellent and in keeping with the health care community's values and demands. Furthermore, as AI evolves, constant training and education will be required of healthcare professionals in order to provide them with the capability to engage with these novel technologies in public health,[9,13,15,16]

Geographical variation in the application of AI in physiotherapy also poses an issue. As certain areas have been developing the implementation of AI within healthcare in an accelerated pace, others remain behind because of an absence of resources, infrastructure, or competence. This geographically uneven provision of AI technologies threatens to heighten current health inequities as some communities might be left deprived of AI-aided physiotherapy's advantages. In order to remedy this, global efforts must be made that support the equal sharing of AI technologies and resources for the purpose that all patients everywhere can have access to these developments in the field of public health.

With these challenges, its integration into physiotherapy is a multi-faceted and complicated affair. Yet the potential rewards far outweigh the challenges, and it is an area of considerable interest and value in healthcare. This manuscript seeks to offer an exhaustive bibliometric overview of current work on AI and physiotherapy, to identify principal trends, key contributors, and cutting-edge research directions. Through mapping the cognitive domain of this rapidly changing discipline, the research attempts to identify seminal gaps in extant literature and provide directions toward future avenues that can further consolidate the use of AI in physiotherapy in the public health context.

The findings of this bibliometric review reflect a high increase in the output of research work on artificial intelligence and physiotherapy between the years 2006–2024, with an uptrend from 2019 to 2022. The trend also reflects the growing recognition of artificial intelligence capabilities to be deployed in physiotherapy applications, particularly telerehabilitation, wearable devices, and predictive modeling. In contrast to earlier research that tends to look at AI in healthcare broadly, for instance,[17] this research specifically targets physiotherapy-related applications, thus providing new perspectives on rehabilitation technologies and their public health implications. It adds to the literature by analyzing geographical inequalities in AI uptake and temporal patterns, giving a holistic picture of the global intellectual environment. Based on sophisticated bibliometric techniques, such as co-citation analysis and bibliographic coupling, as[18] advocated, the intellectual structure of applications of artificial intelligence in physiotherapy is depicted by this research in terms of thematic categories and cognitive relations within the public health field.

The review uncovers the most prominent journals, scientists, nations, and institutions involved in the establishment of this new branch but targets the leaders and the way they connect. The analysis outputs uncover disparities by regions signaling unequal development and integration of AI-based technology within physiotherapy across regions. Future research should aim at addressing ethical issues, regional participation gaps, and low compliance in developing regions that are bound to challenge more collaborative models as more collaboration models are planned to enhance their participation levels. In addition, integrating higher-order artificial intelligence methods into physiotherapy practice and education, such as deep learning, and neural nets, is likely to fundamentally broaden the range of capabilities for the profession. It, thus, emphasizes the importance of practical recommendations for creating well-adjusted and ethical artificial intelligence applications, particularly for the largely under-developed sectors. This lack of knowledge gaps and better understanding obtained ensures that the introduction of artificial intelligence in physiotherapy marks a major leap towards better patient outcomes and efficient care provision in public health.

2. Literature review

A lot of research papers are being conducted to identify and develop uses of Artificial Intelligence in the sphere of medical science and physiotherapy among the public health advancements. To review different formations of AI in medical sciences and physiotherapy, each of which discusses new ideas and approaches and futuristic technology to improve the patient's care of treatment. Relating to the work done by,[19] which proposes an AI technique for human pose estimation during physiotherapy fitness exercises, relates to the study of using machine learning and especially deep learning for improving human movement analysis in the process of exercise correction. Validation of the proposed methods is done using a dataset that captures the movements of various parts of the human skeleton.

Another work of 2023 is based on the incorporation of the application of machine learning models in physiotherapy with special reference to the rehabilitation of a shoulder injury.[20] It emphasizes the application of a 'semi-supervised' model based on the Adaptive Neuro-Fuzzy Inference System (ANFIS) to boost the predictive accuracy of the recovery status. The subsequent studies expand the focus to AI in musculoskeletal physiotherapy, outline how AI assists in the diagnosis, developing a treatment plan, and evaluating outcomes with the stress of supervised and unsupervised machine learning for the analysis of big data derived from the EHR to enhance physiotherapy practices.[9]

Another related study of the same approach encompasses the use of Convolutional neural networks in automating the detection of clinical imaging, an elaboration of using AI-based models in oncology; and an integration of using AI in physical therapy, especially in complying with the right movements to be done by a patient.[21]

Other authors also mention the application of AI in automating and optimizing diagnostic procedures, for example, in the interpretation of imaging modalities in radiology, and in introducing AI devices as aids in planning and performance of surgeries. The possibility of telerehabilitation with AI is an area of concern as this allows patients to access therapy which is unique to their needs using technology that can reach them even from the comfort of their homes. Also, the development of wearable AI technologies used in the clinical environment outside the clinic to help monitor patients' adherence to therapy regimens is also underlined.[22]

In order to present these findings side by side, the information gathered from some of the Research is briefed in tabular form with its objectives, methodologies, outcomes, and relevance to the existing knowledge base of AI and Physiotherapy. Here is the comparative analysis of the research papers on AI applications in medical science and physiotherapy:

Table 1 presents a broad spectrum of research works connected to the use of AI in the sphere of medical science and physiotherapy, including topics such as human pose estimation, optimization of the therapy process, and surgery planning. All the studies employ methods from the AI including machine learning, deep learning, convolutional neural networks, and a combination of these in solving different problems in the medical and physiotherapy fields. For instance,[19] apply MLE in physiotherapy including exercise corrections, and on the other hand AI models in oncology treatment. The contribution of these studies varies from the improvement of diagnosis and recovery prediction to developing a possibility of remote rehabilitation services and increasing the compliance of the patients with therapy regimes, which demonstrates how AI can change almost any aspect of healthcare and treatment. Combined separately these researches prove the constant progress of AI applications in improving the treatment results, and organizational and individual assistance to the patient in medical and physiotherapeutic fields.

3. Research methodology

This section delves into techniques for extracting knowledge gaps and research opportunities from existing empirical literature, drawing upon insights from.[29]

3.1. Analytical instruments

This investigation used the software programs Canva, Excel, and RStudio. R Studio is deployed for analysis of bibliometric data since it is an integrated development environment (IDE) for the R programming language. Specifically, the Biblioshiny package in R was utilized for bibliometric performance analysis and science mapping. In addition to this Canva, MS-Excel and Data-wrapper were utilized to enhance the visualizations created by biblioshiny, an R package. Creating an efficient and cohesive work environment is the primary goal of the open-source project called RStudio, which integrates many R programming language features such as source editing, console, history, and graphics and helps it become a unified and efficient workplace .[30] This study generates networks using biblioshiny, incorporating scholars, publications, nations, keywords, and ideas. Addressing the limitations of RStudio's visual editing features, we employed additional tools such as Canva, Data-wrapper and Microsoft Excel to create editable tables and figures. Content analysis played a crucial role in identifying gaps within the existing literature. To strengthen analytical rigor, the bibliometric performance indicators used include the h-index, g-index, total citation counts, average citations per year, betweenness centrality in collaboration networks, modularity class detection for thematic clusters, and citation bursts to identify emerging trends. Threshold criteria were set to ensure quality analysis: authors and keywords included had to appear in at least three documents, and documents required a minimum of five citations for impact analysis.

Table 1
Researches in the field of physiotherapy using AI.

Research	Year	Focus	Methodology	Significance
LogRF for Physiotherapy Pose Estimation[19]	2023	Human pose estimation in physiotherapy	Machine learning and deep learning	Enhances exercise correction and assessment
Hybrid ANFIS Model for Shoulder Rehab[20]	2023	Shoulder injury rehabilitation	Hybrid model using ANFIS	Improves prediction of recovery outcomes
AI in Musculoskeletal Physiotherapy[22]	2023	Diagnostics and treatment planning in physiotherapy	Supervised and unsupervised machine learning	Improves diagnostics and treatment outcomes
AI in Personalized Oncology Treatments.[23]	2023	Personalization of medicine in oncology	AI-driven models	Enables personalized treatment approaches
AI Optimization of Physical Therapy Routines[24]	2023	Optimization of physical therapy routines	Movement tracking and analysis	Optimizes therapy by precise movement tracking
AI-Powered Medical Imaging Interpretation.[25]	2023	Interpretation of medical imaging	Automated diagnostic processes	Enhances accuracy and speed of image interpretation
AI in Surgical Planning and Execution[26]	2023	Assistance in surgical planning and execution	AI tools integration	Facilitates precise and efficient surgical procedures
AI-Powered Tele-Rehabilitation Services.[27]	2023	Providing telerehabilitation services	Remote personalized therapy	Allows continuous remote monitoring and therapy
Wearable AI for Patient Compliance[28]	2023	Monitoring and improving therapy compliance	Wearable AI technologies	Enhances adherence to prescribed therapy regimes

3.2. Bibliometric methodology

In 1969, Pritchard defined bibliometrics as "the application of mathematical and statistical methods to articles and other forms of communication"[31]). This quantitative methodology presents a distinctive lens through which to assess the advancement of a discipline, reducing researcher bias and facilitating a comprehensive understanding. The ability to cope with a large amount of information and objective features makes bibliometric analysis instrumental in detecting intellectual trends and research impact assessments,[18,32] Bibliometric techniques hold special importance for emerging interdisciplinary fields such as artificial intelligence and physiotherapy, where fragmented investigation and the emergent nature of topics necessitate sound scrutiny to identify trends and gaps.

Although this study utilized keyword frequency-based co-occurrence analysis for thematic evaluation, future research could incorporate advanced topic modeling techniques, such as Latent Dirichlet Allocation (LDA). LDA can uncover deeper latent thematic structures by identifying hidden topic distributions across documents, offering a probabilistic and automated alternative to manual keyword mapping. The application of LDA would enhance the granularity of thematic evolution insights, particularly beneficial for a rapidly expanding interdisciplinary domain like AI in physiotherapy.

There are two dominant bibliometric approaches: scientific mapping and performance analysis.[33] Scientific mapping depicts some areas' cognitive structure and new research.[34] Conversely, using bibliometric data, performance analysis examines the impacts of authors, countries, journals, and publications,[18].[35] These methods help identify latent trends, leading performers, and the trends that guide specialty fields like artificial intelligence in physiotherapy. Bibliometric analysis is a detailed assessment of all bibliographic information. It encompasses citations, publication and co-citation patterns, source names, origins of research, and the impact of citations.[36] Scholars can use these methods to study the research environment more and make action recommendations.

Performance analysis is important as it helps to understand how knowledge is spread and received in a particular field. Two common approaches within performance analysis are evaluative assessment and citation analysis. An evaluative analysis also looks at publication and citation metrics but tries to explain the reasons behind the efforts behind these articles' production and marketing. This type of work is directed to causes of interest and influencing factors,[18],[29].[35] What is described above is complimented by citation analysis. Through these definitions, it becomes possible to evaluate the relative contributions of scholars, nations, journals, and all citation-published work according to the citation volume each has received.[18] Moreover, scientific modeling tools form feature networks from articles' characteristics, making it possible to uncover such dormant areas and relationships important for studying the intellectual structure of fast-changing areas such as artificial intelligence physiotherapists.

Although Biblioshiny was used for analysis, its known limitations were considered: duplicate author names due to naming conventions, affiliation misclassifications, and its lack of built-in topic modeling (such as LDA) features. Manual verification and cleaning were applied where necessary to maintain data integrity.

This research uses bibliometric analysis to frame the research activity at the boundary of AI and physiotherapy in additional context. It identifies foremost countries, major journals, important authors, significant contributions, and important phrases commonly used, and it helps create boundaries between the critical factors of AI and physiotherapy reviews. Additionally, using bibliometric methods such as co-citation and research clusters created by authors, it is possible to represent in graphic form the relations of ideas, themes, and development of research areas.[37] Such approaches shed light on AI's evolution in physiotherapy and its prospects in precision rehabilitation, telerehabilitation, and wearable technology development. Optimization techniques, such as the Jaya algorithm applied to critical system reliability problems, offer valuable methodological insights that can further enhance AI model performance in physiotherapy rehabilitation settings[38]

This systematic and quantitative approach aims to fill in the knowledge gaps in the literature, determine the major players, and develop recommendations for further research and policymaking in this area. This bibliometric study is the first effort to evaluate all aspects of research in AI as it relates to physiotherapy, providing new information on the conceptual framework in this field of interrelated systems. In the conducted research, trends, contributors, and thematic clusters are mapped, making it possible to document the movement more holistically and neutrally with recognition of the achievements and challenges that still exist. It sets the stage for greater incorporation of AI technologies into physiotherapy practice, thereby enhancing patient care and healthcare services' efficiency.

3.3. Sample selection process

As depicted in Fig. 1, our approach is based on established practices widely used in bibliometric analysis, as highlighted in the study by.[39] Following their guidelines, we adopted traditional procedures to conduct a thorough bibliometric analysis, allowing for a systematic examination of the complex aspects of academic literature within our chosen field[35]

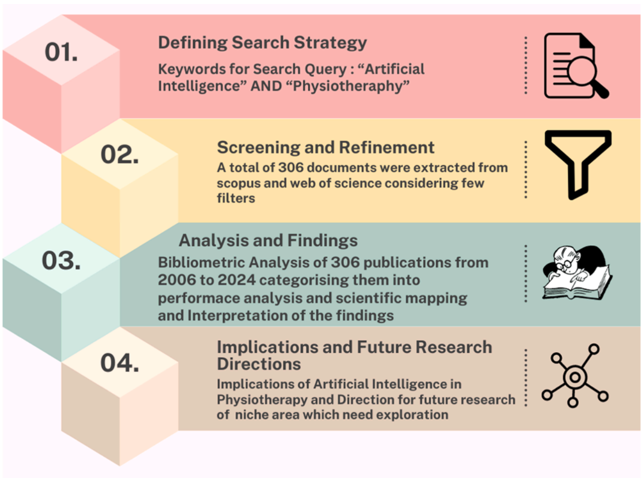

Fig. 1. Literature search and screening criteria.

3.4. Search strategy

An essential and challenging step in bibliometric analysis is the identification of relevant research articles, which depends on setting appropriate search criteria and selecting a suitable database.[18] The documents are sourced from Scopus and Web of Science (WoS) due to their extensive coverage, widespread recognition, and high-quality standards,[40].[41–43] The search query used was TITLE-ABS-KEY ("Artificial Intelligence" OR "AI") AND ("Physiotherapy" OR "Physio" OR "PT") to ensure broad coverage across healthcare and rehabilitation terminologies. This search, performed in July 2024, resulted in 377 records from Scopus (185 documents) and WOS (192 documents). Following the removal of 35 duplicate records and one ineligible record identified through automated tools, a total of 341 records were screened for relevance. At this stage, one record was excluded, leaving 340 reports to be assessed for retrieval. All 340 documents were successfully retrieved, with no exclusions.

These 340 documents were checked during the eligibility assessment stage to determine whether they met the pre-defined inclusion criteria. At this stage, there were no such exclusions, thus confirming both the search strategy's effectiveness and the definition of the eligibility parameters. Thus, 340 studies were finally included in this review. In this process, the study makes use of a generous approach to identifying the literature that is relevant to the literature review and study design as can be seen in the PRISMA framework flow diagram as in Fig. 2. The systematic and transparent approach that is employed in this case helps to achieve broad coverage of the research area of interest while ensuring that the selection bias is minimized.[44] This rigor in the process also improves the reliability of the bibliometric analysis. It provides a unique perspective on understanding the communicative structure and research patterns in a fast-emerging area of physiotherapy and artificial intelligence (AI).

3.5. Research questions

The following questions define the study's primary goal: to present the state of Artificial Intelligence in Physiotherapy research.

RQ 1: What are AI and physiotherapy research's descriptive statistics and development trends?

RQ 2: How has publication activity in AI and physiotherapy evolved?

RQ 3: How has scientific mapping in AI and physiotherapy changed in recent decades?

RQ 4: What are the recent trends and changes in AI and physiotherapy research?

RQ 5: What are the future research directions in AI and physiotherapy?

Moreover, our research adds to the corpus of prior work by

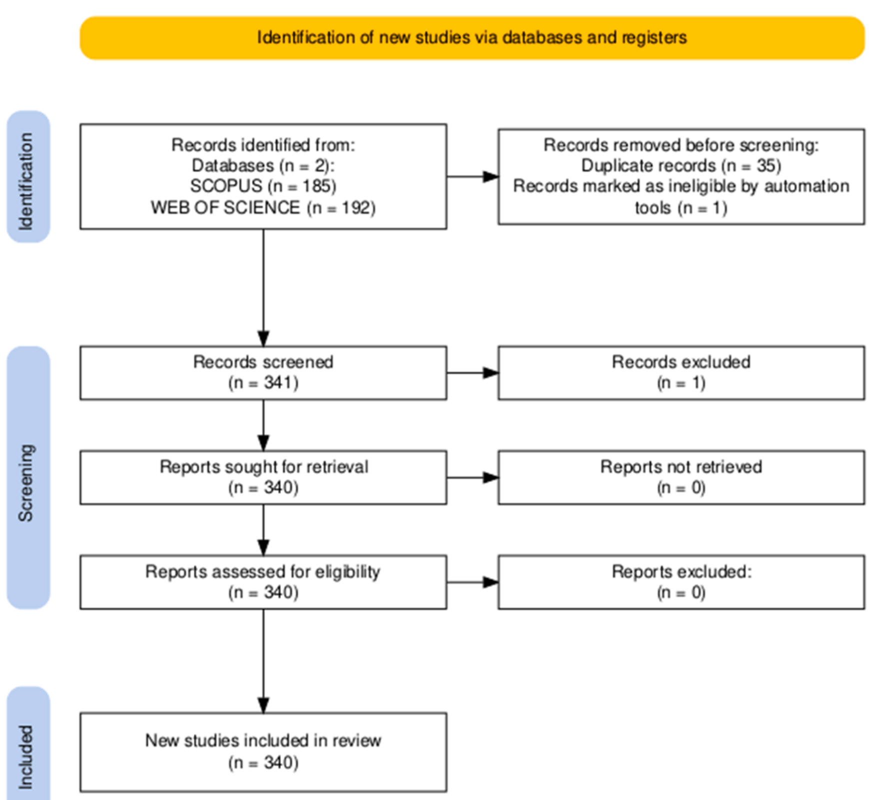

Fig. 2. PRISMA Framework.

deepening and improving our understanding of Artificial Intelligence in Physiotherapy research.

4. Results

4.1. Performance analysis

4.1.1. Descriptive statistics

The statistical infographic represents an overview of the source for a research dataset from 2006 to 2024. As illustrated in Fig. 3, Some of the key indicators were total sources, at 235, the sum of documents standing at 340, and that of authors at 3301. The rate of growth stood at 15.9 %. Collaboration indicators included an international co-authorship rate of 25.59 % and an average of 13.3 authors per document. There are 1089 author keywords in the dataset. On average, papers' age is 2.85 years, with 9.185 citations per paper. These metrics relate to the size of the dataset, its growth, collaboration patterns, and, from another standpoint, how much impact the research has had.

4.1.2. Annual scientific production

The line graph of annual scientific production from 2006 to 2024. The years are plotted on the x-axis, and the number of articles on the y-axis. The graph in Fig. 4 represents the gradual rise from 2006 to 2018 and then a steep growth from 2019 to 2022, with a slight drop in the years 2023 and 2024. The impressive upward trend in physiotherapy and AI publications can be credited mainly to the swift advancements in cutting-edge technologies, such as wearable devices, artificial intelligence algorithms, and robotics in healthcare. As these innovations gain traction in physiotherapy and AI, they not only enhance patient care but also ignite significant research interest, leading to a surge in publication activity. While the recent slight decline is more likely a natural adjustment following an initial spike in interest or a temporary delay in disseminating groundbreaking research findings. Embracing these technologies is essential for physiotherapy's future and patients' well-being. This upward trend can be attributed to the rapid development of advanced technologies, such as wearable devices, AI algorithms, and robotics for healthcare, and their increasing adoption in physiotherapy during this period. These innovations have driven significant research interest and publication activity. The slight decline in recent years may reflect the natural leveling off following the initial surge or delays in publishing emerging research outcomes. An observed slight decline in publication outputs after 2023 appears to be more reflective of database indexing delays rather than an actual downturn in research activity. Given the ongoing surge of preprints, conference proceedings, and newly initiated research projects in physiotherapy AI applications, it is likely that these outputs have not yet been fully captured in indexed repositories such as Scopus and WoS. Therefore, the decline should be interpreted cautiously and may represent a temporary bibliometric artifact rather than a genuine decrease in research momentum.

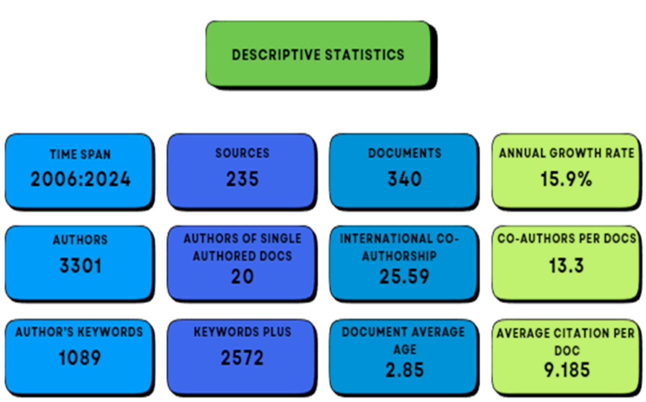

Fig. 3. Main information.

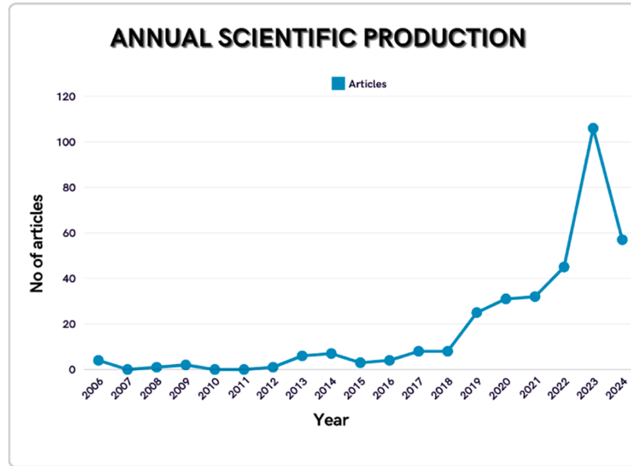

Fig. 4. Annual scientific production.

4.1.3. Average citations per year

Average citations, illustrated in Fig. 5, the line graph of the average number of times the works have been cited per year and per article from 2006 to 2023. On the x-axis, it contains the years, while on the y-axis, it includes an average count of citation. The data has big fluctuations. It reached a peak in 2019, then the trend goes down, which may indicate variable research impacts at different times indicating that research field is evolving, and the existing body of research continues to serve as a foundation, with researchers actively citing prior studies to build upon established knowledge and explore emerging trends.

4.1.4. Three field plot

The plot of these three fields in Fig. 6 offers an image of a network interlacing data points arranged in three major fields: authors, countries, and research topics in AI and physiotherapy. Rahman M. emerges from the above network as a prolific author with affiliations and dominant terms in multiple countries, making his contribution prominent. The USA, the UK, Iran, and India are the main coordinators of a global joint research and development center that covers all the significant subjects in AI, machine learning, physiotherapy, and telerehabilitation, and it explores rich areas, as well as the new areas of deep learning, robotics, and virtual reality, with the lowest levels of connecting interests that are seen in the progress of this field. The pattern also indicates a serious under-representation of the global input with respect to the developing regions, which are mainly dilapidated, highlighting global disparities, with limited contributions from developing regions, underscoring

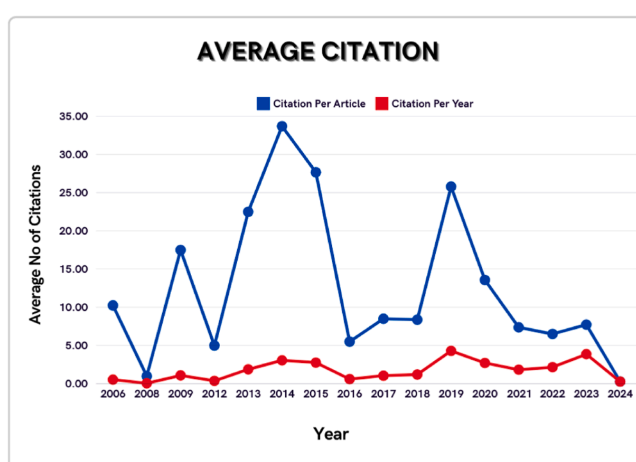

Fig. 5. Average citations per year.

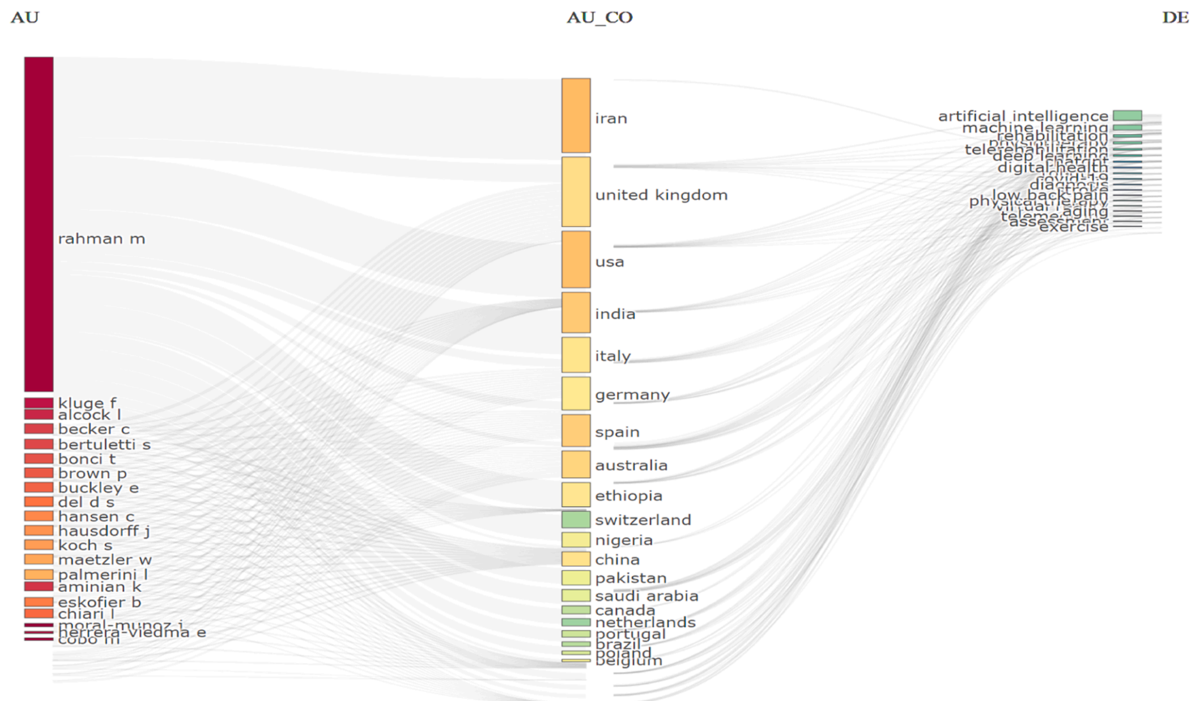

Fig. 6. Three field plot.

collaboration opportunities.

4.1.5. Most relevant sources

Sources are of high relevance to bibliometric research since they indicate the number of articles they contribute as it can be observed in Fig. 7. SENSORS tops the list with 16 articles, showing that it really has a critical role in technologies of data monitoring applicable to quantum computing and machine learning.The next in line is APPLIED SCIENCES-BASEL, with 10 articles contributing to good breadth of applied sciences relevant to the practical application field of your research. Then again, JOURNAL OF MEDICAL INTERNET RESEARCH and SCIENTIFIC REPORTS have 7 articles each, relating what is necessary for medical technology and multidisciplinary scientific research. IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING adds 6, providing the crucially relevant views of the engineering aspects of neural systems that overlap with machine learning and security. These sources are collectively sufficient to build a foundation on which to base the intersections between quantum computing, security, and machine learning.

Sources production over time can be observed in Fig. 8, the line graph that SENSORS has demonstrated outrageous growth in article production, peaking at 16 articles within recent years. APPLIED SCIENCES-BASEL and JOURNAL OF MEDICAL INTERNET RESEARCH increase rather steadily their contributions; in 2024, APPLIED SCIENCES-BASEL has already published 10 articles, while JOURNAL OF MEDICAL INTERNET RESEARCH has already published 7 articles. SCIENTIFIC REPORTS has stable output, peaking at 7 articles, and IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING together with INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH represent a moderate increase with 6 articles. It is followed by ARTIFICIAL INTELLIGENCE IN MEDICINE and JOURNAL OF NEUROENGINEERING AND REHABILITATION, both on an increasing trend and hosting 5 articles each. LECTURE NOTES IN COMPUTER SCIENCE and STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS have a steady output, with a slight increase to 5 articles that shows their continued relevance to the fields.

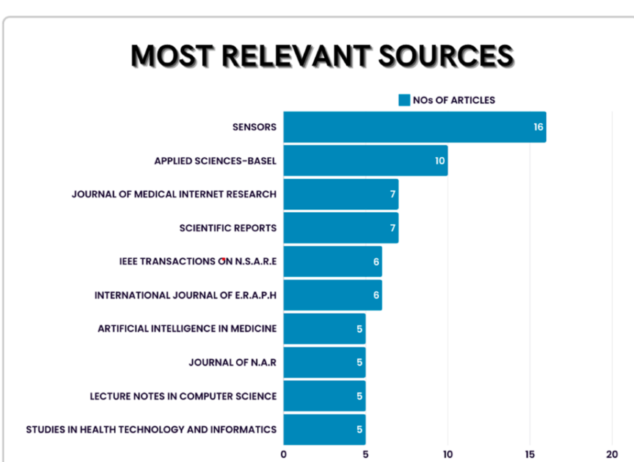

Fig. 7. Most relevant sources.

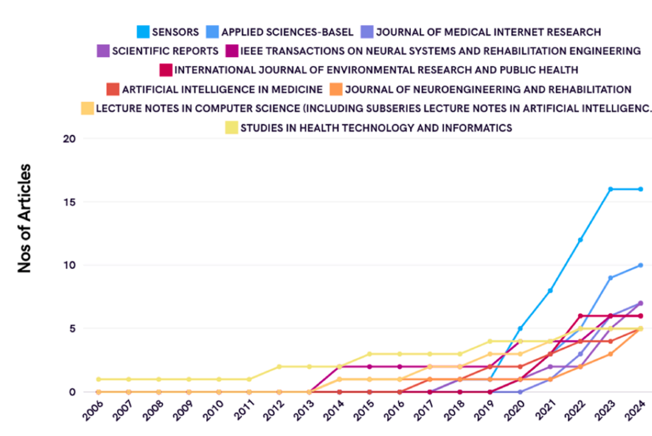

Fig. 8. Sources' production over time.

4.1.6. Bradford's law

Bradford's Law`s plot as can be seen in Fig. 9, for the scatter of publications in scientific journals can be explained by dividing it into three different zones according to their frequency of appearance. In Zone 1, journals most frequently cited, such as SENSORS and APPLIED SCIENCES-BASEL, have very high citation counts and are key sources contributing much to the field. Zone 2 contains journals with a lower, but still remarkable, frequency of citations; zone 3 includes less frequently cited publications, hence showing an increasingly wider and less concentrated distribution of research output. This trend exemplifies Bradford's Law through the expression of the core group of high-impact journals widely cited and a progressively increasing number of less frequently cited sources.

The overlapping of journal names in the Bradford's Law graph from Biblioshiny occurs due to the compressed x-axis based on logarithmic ranking, which places many high-ranking journals close together. Combined with long journal names and vertical label orientation, this leads to visual clutter. Since Biblioshiny uses static ggplot2 rendering, it doesn't dynamically adjust label spacing by default.

The core journals visible in the graph include: Sensors, Applied Sciences-Basel, Journal of Medical Internet Research, Scientific Reports, IEEE Transactions on Neural Networks and Learning Systems, International Journal of Environmental Research and Public Health, Artificial Intelligence in Medicine, and others up to Expert Systems with Applications.

4.1.7. Author productivity through Lotka's law

Evidence for an inverse square law distribution of scientific productivity among authors is found in applying Lotka's Law as can be observed in Fig. 10. There are very few productive authors, a fair number of moderately productive authors, and a huge number of authors with meager productivity. In this concrete dataset, 2583 authors published only one article each, which is 78.2 percent, and the number of those publishing two articles is 472, or 14.3 percent. Clearly, the greater the number of publications, the fewer the number of authors; only 19 have four articles, 11 five, and the numbers drop even lower for higher publication counts. This distribution follows Lotka's principle in that a small percentage of authors is contributing a disproportionately large share of publications, with most being less productive.

4.1.8. Most relevant authors

The tabulated data as in Table 2, provides a detailed analysis of the contributions of key authors in AI and physiotherapy research, reflecting both their total article counts and fractionalized impacts. MORAL-MUNOZ J, for instance, leads with 13 total articles but a lower fractionalized impact (2.69), suggesting collaborative work involving many co-authors. In contrast, RAHMAN M, with 11 articles and a fractionalized count of 0.0166, likely represents significant individual contributions. Authors like COBO M and HERRERA-VIEDMA E balance high total outputs with notable fractionalized impacts, indicating strong individual influence in collaborative contexts. This comparison highlights both prolific researchers and those with concentrated individual impact, revealing patterns of collaboration and individual influence within the field. The combination of visual and tabular data provides a nuanced perspective, showcasing the interplay of collective and individual contributions to advancing AI-driven physiotherapy research.

4.1.9. Authors production over time

This Fig. 11 is of a scatter plot following the publication activity of several authors from 2013 to 2024. In the plot shown, the x-axis is time in years, and the y-axis lists authors. Each point corresponds to a publication of an author in the specific year; the size of the dot relates to the number of publications. The scatter plot shows that publication rates vary a good deal across authors. Some have larger publication activities, while others have less frequent output. The general trend in publications is upwards towards the later years. From the data appear that the most prolific author was RAHMAN M.

4.1.10. Most relevant affiliations

The affiliation graph in Fig. 12, visualizes the research output from different institutions. The view expressed is that TEHRAN UNIVERSITY OF MEDICAL SCIENCES publishes highest number of articles, 71 articles, hence representing the highest research activity. SHAHID BEHESHTI UNIVERSITY MEDICAL SCIENCES is next in the line, with 47 articles, followed by VRIJE UNIVERSITEIT BRUSSEL and UNIVERSIDAD DE CADIZ, which have published 36 and 34 articles, respectively. HARVARD UNIVERSITY and MANIPAL ACADEMY OF HIGHER EDUCATION contribute 31 and 30 articles, respectively, thus showing quite a contribution but relatively lower. Other institutions that contributed to this area were EGYPTIAN KNOWLEDGE BANK, UNIVERSITY OF SHEFFIELD, TABRIZ UNIVERSITY OF MEDICAL SCIENCE, and

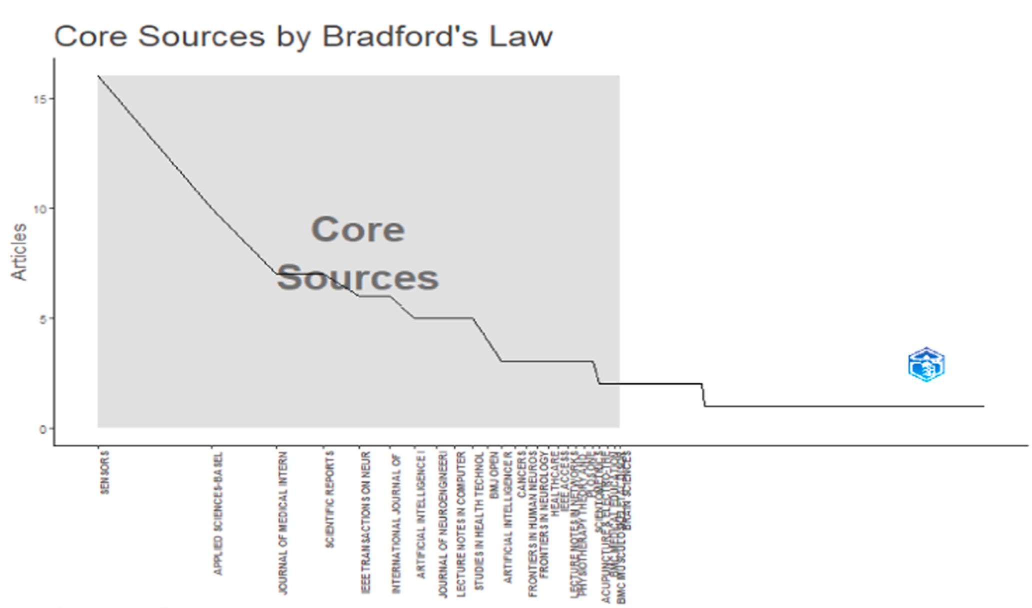

Fig. 9. Core sources by bradford's law.

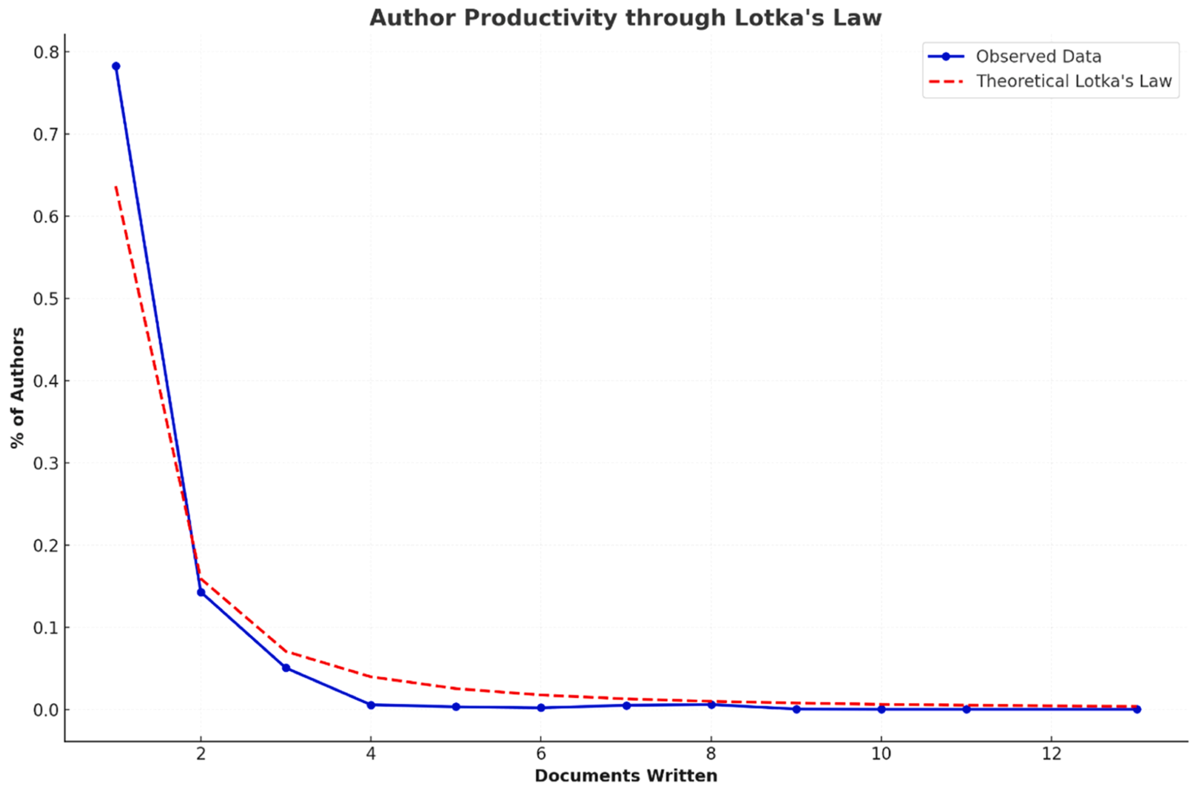

Fig. 10. Author productivity through Lotka's law.

Table 2
Most relevant authors.

Authors	Articles	Articles Fractionalized
MORAL-MUNOZ J	13	2.692857143
RAHMAN M	11	0.01665714308
COBO M	10	2.183333333
HERRERA-VIEDMA E	9	1.8
KLUGE F	9	0.1761198485
ALCOCK L	8	0.1345784397
AMINIAN K	8	0.1734673286
BECKER C	8	0.1345784397
BERTULETTI S	8	0.1345784397
BONCI T	8	0.1345784397

UNIVERSITY COLLEGE DUBLIN, with contributions ranging from 28 to 24 articles. This graph puts across, succinctly, the top institutions and their relative research outputs in the area under study.

4.1.11. Affiliation production over time

The line graph illustrated in Fig. 13 detailing affiliation production over time shows major trends in the output of research across users. UNIVERSITY COLLEGE DUBLIN, represented by the cumulative constant output line, has an upward trend from 2006 to 2020, culminating in a very aggressive increase in the last few years, with a peak of 24 articles forecast to be published in 2024. UNIVERSIDAD DE CADIZ shows no outputs until 2017, with an increase in the line from that point until 2024 and a strong increase up to 34 articles. TABRIZ UNIVERSITY OF MEDICAL SCIENCE also had no record before 2021 and then increased sharply to 24 by 2024. Both UNIVERSITY OF SHEFFIELD and VRIJE UNIVERSITEIT BRUSSEL had no record until 2021; the thereafter line for the University of Sheffield moved up sharply, while that for VRIJE UNIVERSITEIT BRUSSEL shows moderate growth. EKB had no output from 2006 up to 2021 but was able to produce 28 from both 2023 and 2024. As of 2023, there were no publications from HARVARD UNIVERSITY and MANIPAL ACADEMY OF HIGHER EDUCATION; as of 2024, both contributed 30. SHAHID BEHESHTI UNIVERSITY MEDICAL SCIENCES and TEHRAN UNIVERSITY OF MEDICAL SCIENCES just had their first publication in 2023 and finished 47 articles this 2024. This graph very much explains the variation and increase of the research output from the institutions over time.

4.1.12. Country scientific production

The coloring of the map in Fig. 14 is based on the amount of scientific production of a country. Darker shades of blue, as in Iran and The United States and then the change in color pallet towards yellow in India, Spain, Australia, United Kingdom China, Italy, and Ethiopia indicate a larger output; yellow shades, as in most countries in Africa and South America, a small one. This picture thus shows regional inequalities in scientific production, where prominent contributors come from North America, Europe, and parts of Asia.

4.1.13. Country production over time

Countries production over time can be observed from Fig. 15, which shows growth in research production over a period for several countries. Germany shows steady but slow growth from 2006 to 2019, then, starting from a surge of publications in 2020, peaks in 2024. India shows gradual growth but had a rapid rise of publications starting in 2023, which reflects an outbreak of research activity. The contribution of Spain is constantly increasing, and the number of articles increased in 2013, with the highest peak of publications in 2024. The United Kingdom shares a similar trend to this case, so it has been developing in the same way: there is a large increase in production starting from 2020; it continued its rise in 2024. The USA remained the same, peaking in recent years, mostly in 2023 and 2024. The increase in China is more gradual but showed a big rise in recent years, peaking in 2024. Italy followed an increasing trajectory and steeply rose in terms of articles in the recent past. The case for Australia is that of modest growth at the very beginning and then shooting up in the recent past. Iran: Publications have increased at a rapid rate from 2021 to 2024. Now, when it comes to Ethiopia, it remained flat up to 2023 and has seen quite a

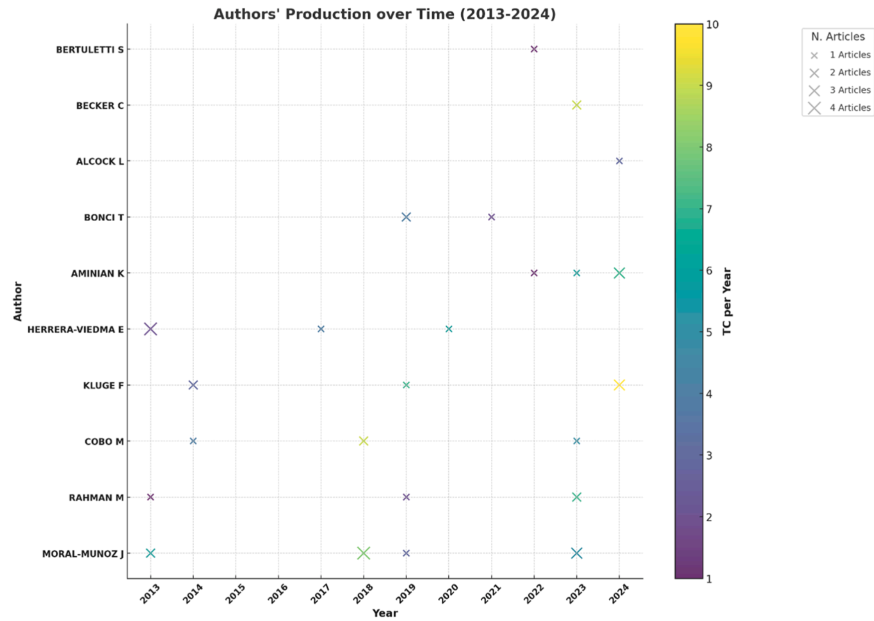

Fig. 11. Authors production over time.

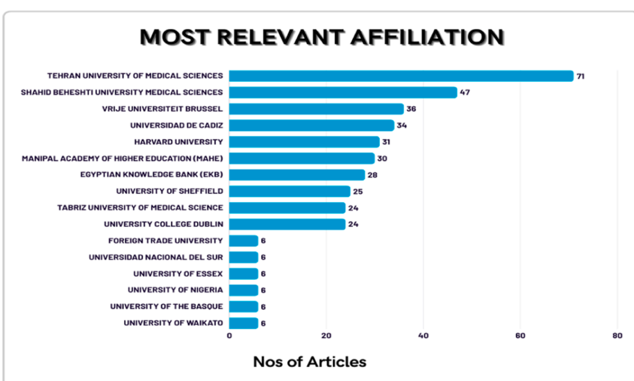

Fig. 12. Most relevant affiliations.

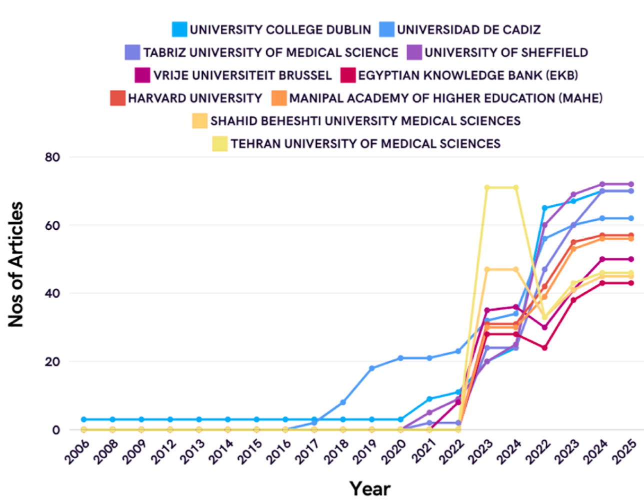

Fig. 13. Affiliations' production over time.

marked increase. In other words, this statistic goes on to tell us that though the trend of research output is increasing in the world at large, in certain countries, particularly in the last couple of years, it has seen a rapid increase.

4.1.14. Most cited countries

These countries are the most cited as shown in Fig. 16, ranging from high total to high average impacts. The USA has the most total citations with 571 and is very high in average impact per article at 28.6, showing very strong research influence. Next came Spain, with a high total number of citations but at a low average impact per article of 9.8. China has high research output, with a total of 268 and an average of 7.4. The United Kingdom itself has a solid citation count, with 167, at a moderate average of 13.9. France and Australia have large average citations per article, but lower total citations, which suggests their focused impact. Canada is poor in total number at 102 but has a large average citation per article of 25.5, while Germany has the lowest average citation among these top countries, with 5.1 and a total of 92. Portugal and Korea have totals of 87 and 86, respectively, together with average impacts of 12.4 and 17.2, respectively.

4.1.15. Most global cited documents

Most globally cited papers rank very high in research impact on many diversified subjects as in Fig. 17. Back in 2023, ONG K. was ranked the top in The Lancet with 466 total citations. His work therefore had a great influence on the medical fraternity. TRAN V. ranks second in 2019 on NPJ Digital Medicine, having 128 citations; hence, he has left his mark in the research into digital health. In Journal Gait & Posture, CLARK R has an article in 2019 with 118 citations; this work is very fundamental in gait-schedule analysis and posture studies. Journal of Neuro Engineering and Rehabilitation published a paper by XIAO Z in 2014 that is relatively highly cited, with 98 citations, related to neuro engineering. Some research pointing out the material science in it, published by ZHENG X in Composites Part A: Applied Science and Manufacturing, was cited 77 times in 2022. The article of LEE S, 2015, with 75 citations in PLOS ONE, proves it of interest to many different fields. In the same way, the paper published by LUCIW M in Scientific Data in 2014 gets 69 citations, supporting its contribution to data science. A paper by ROWE M published in Academic Medicine in 2019 and the study by TACK C, published in 2019 in Musculoskeletal Science and Practice, get 61 and 60 citations, respectively, thus underpinning its

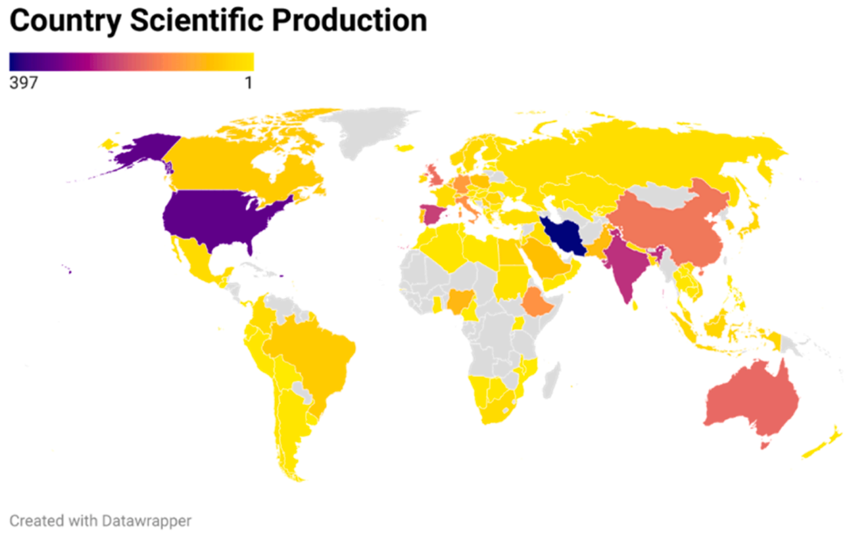

Fig. 14. Country scientific production.

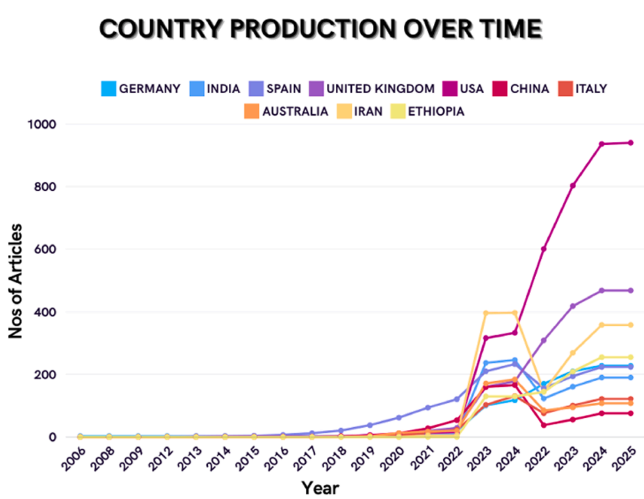

Fig. 15. Country production over time.

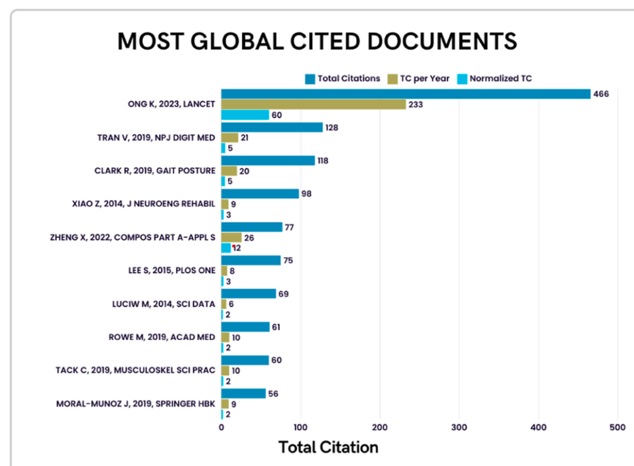

Fig. 17. Most global cited documents.

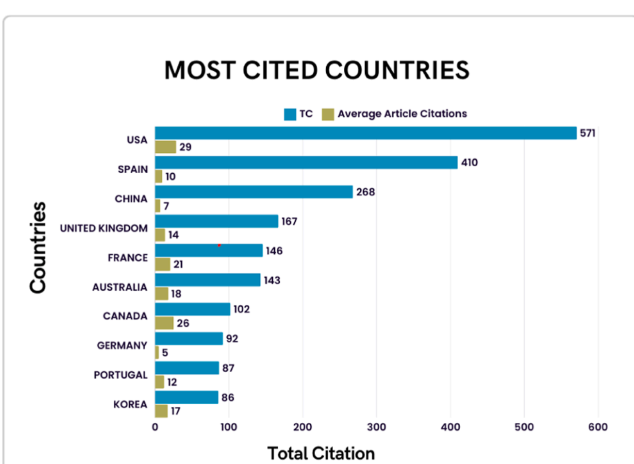

Fig. 16. Most cited countries.

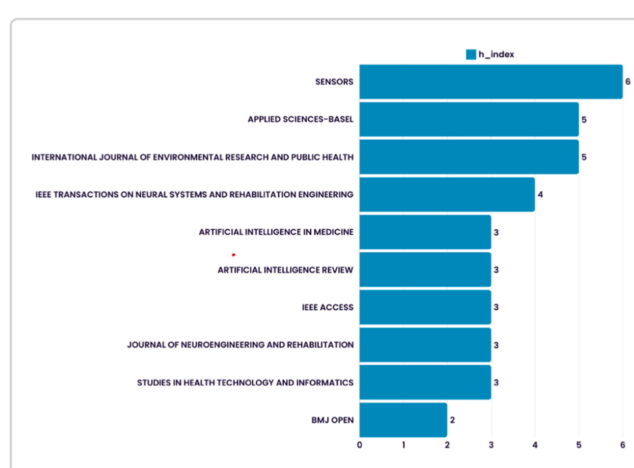

Fig. 18. Sources local impact by H-index.

impact on medical and musculoskeletal research. The last contribution, the 2019 chapter by MORAL-MUNOZ J in Springer Handbook, has already received 56 citations, which is very important for academic reference materials.

4.2. Science mapping

4.2.1. Sources local impact by H-index

The impact of the sources at the local level can be seen in Fig. 18, as captured by their h-index, shows that they affect and are cited by other sources in their fields. SENSORS leads the list with an h-index of 6, showing a high count of citation and consequent impact on research in the sensor technology area. On the level of scholarly influence, APPLIED SCIENCES-BASEL and INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH rank next to each other, with an h-index of 5. IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING: It has an h-index of 4, which immediately places it as a central area where neural systems research is making a significant impact. Journals such as ARTIFICIAL INTELLIGENCE IN MEDICINE, ARTIFICIAL INTELLIGENCE REVIEW, IEEE ACCESS, JOURNAL OF NEUROENGINEERING AND REHABILITATION, and STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS each have an h-index of 3 and are of medium impact. BMJ OPEN has an h-index of 2, which indicates a rather smaller citation footprint.

4.2.2. Author local impact by H-index

As observed in Fig. 19, It is a measure of the impact of an author that signifies the number of his most cited papers, where each of them earned at least as many citations as its value of the h-index. Example: Topping this list is RAHMAN M, with an h-index of 11, meaning he would have much influence from a few highly cited works. The following are HERRERA-VIEDMA E and MORAL-MUNOZ J, who have an index of 8, indicating a fair amount but of lesser influence compared with the former. Less heavy hitters—COBO M, GUPTA V, LEE S, with an h-index of 7—and AHMED A, REZAEI N, KHAN M, LE T —make a less pronounced impact but contribute enormously to the field. The h-index gives a bird's eye view of the sustained research influence for a given principal investigator. The higher its value, the more substantial and influential a contribution has been.

4.2.3. Corresponding authors countries

It translates to mean that the research output and patterns of collaboration vary by country as illustrated in Fig. 20. Spain publishes 42 articles, thereby proving there is a firm national research base with considerable international collaboration since it contains 33 SCP and 9 MCP. The second is China, with 36 articles, and it has also maintained high numbers with both SCP (27) and MCP (9), which quite logically leads to high domestic and international research activity. The USA contributes 20 articles with a focus on national research (16 SCP) and less international collaboration (4 MCP). Other countries, like Italy and Germany, appear to be more balanced. In Italy, there is an equal share of SCP and MCP, while in Germany, there are more SCP—12—than MCP—6. The country, like India and the UK, has different emphases: India towards SCP and UK towards MCP. That is to say, all in all, research productivity mirrors a heterogeneous landscape of concentration in national contribution by some countries and others striking a middle path between national and international contributions.

4.2.4. Keywords analysis

The latest keywords are mainly related to those fields in which the highest relevance of recent research stands is observed in Fig. 21. The leader of the list is the term "artificial intelligence", with 83 occurrences leading to the highest relevance of recent research. The next leading term is "machine learning", with 35 occurrences, which implies its importance in data-oriented analysis and model development. The occurrence figures for "physiotherapy" and "rehabiltition" are 32 and 31, respectively, which reflects the importance and central research trend related to therapeutic studies. These terms are used less frequently—10 times or fewer: telerehabilitation, deep learning, virtual reality—all suggestive of emerging technologies/techniques within the domain. Another pair of 9-time words is physical therapy and robotics, which fits the use of the physical drive and appliance as well. Covid-19, naturally, has already occurred in recent research ways a total of 8 times.

A line graph in Fig. 22 represents the changing research topics from 2006 to 2024. Artificial Intelligence and Machine Learning, with some spiky growth, have mounted to the peaks since the year 2019, representing the increasing importance of the topics in the field. With an exponentially increasing trajectory, the topics of Physiotherapy and Rehabilitation have now begun showing very significant increments in more recent years. Likewise, Telerehabilitation and Deep Learning are

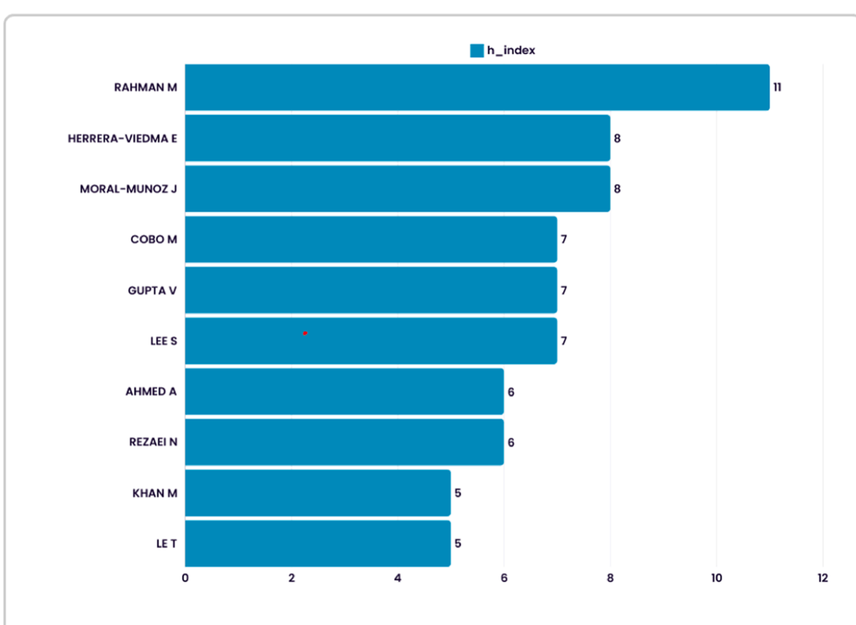

Fig. 19. Author local impact by H-index.

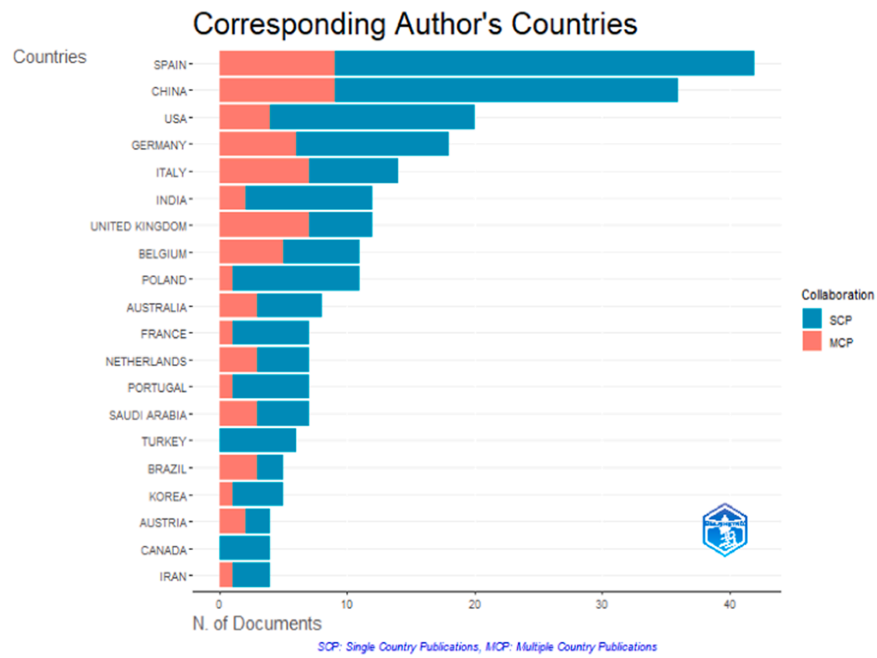

Fig. 20. Corresponding authors countries.

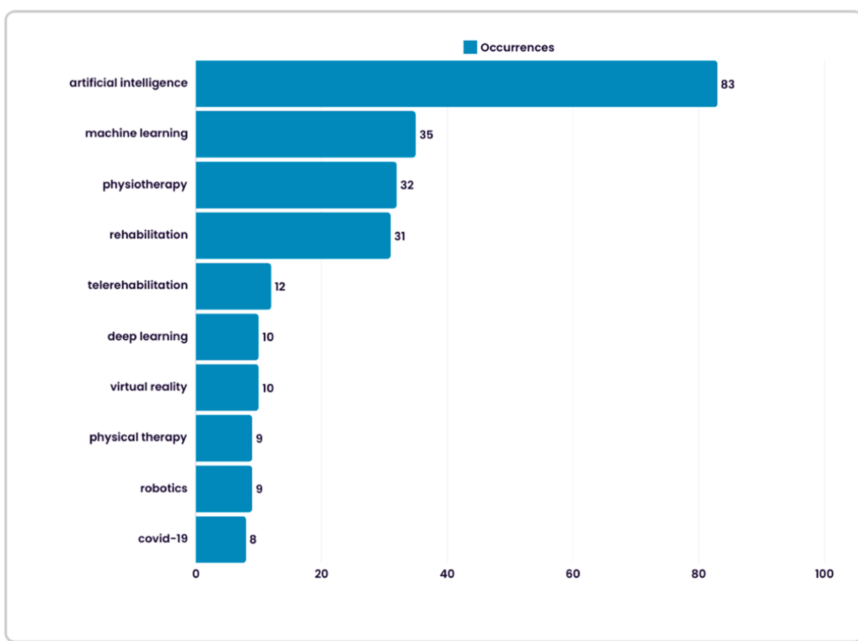

Fig. 21. Most relevant keywords.

slow but significant growing topics now. The trends are more static in Virtual Reality, Physical Therapy, and Robotics, with only moderate rises. The term Covid-19 was most evident in the years of the pandemic, indicating the way in which it affected research. Overall, this points to an uptick in advanced technologies and maintained interest in respect of therapeutic fields.

4.2.5. Co-occurrence network

Fig. 23 is the co-occurrence network of keywords, providing a meaningful visualization of thematic clustering in the overlap of artificial intelligence and physiotherapy. Nodes are keywords, with size proportional to frequency, and edges represent the strength of co-occurrence. The network shows a prominent central cluster centered on "artificial intelligence" and "physiotherapy," reflecting their central interconnectedness in the research context. Around this central cluster, smaller, specialized clusters appear:

- Biomechanics, sensors, and deep learning constitute a closely related set proposing technical innovations in patient monitoring and movement analysis.
- Rehabilitation, robotics, telemedicine, and virtual reality constitute another salient cluster emphasizing technology-based therapeutic interventions.
- Peripheral nodes such as "aging," "Parkinson's disease," and "musculoskeletal pain" point towards disease-specific research topics but show weaker connectivity with the core network, pointing

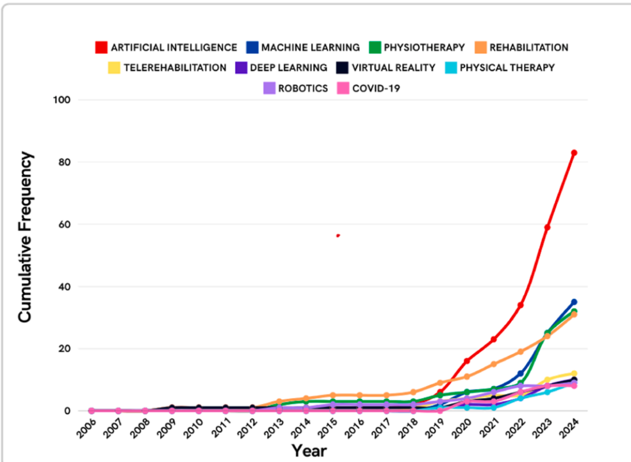

Fig. 22. Words frequency over time.

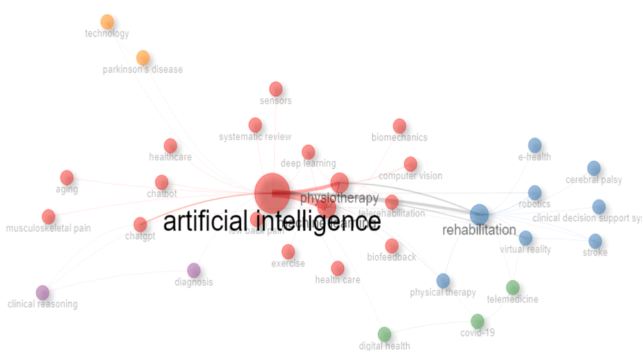

Fig. 23. Co-occurrence network of keywords.

towards potential research gaps in using AI extensively in different clinical diseases.

Structural gaps can be observed where certain keywords, such as "clinical decision support system" and "cerebral palsy," are relatively disconnected. This suggests that although interest is increasing, AI-powered decision-making systems and pediatric rehabilitation are under-researched in physiotherapy research.

Regional or topical differences can also be inferred: New topics such as "chatbots" and "COVID-19" emerge on the periphery, indicating that although these topics have recently become more prominent, they are not yet highly integrated into mainstream physiotherapy research.

1. This structural analysis points to two main barriers: Few cross-linkages between technological innovation (e.g., digital health) and rehabilitation outcomes research.
2. Lack of representation of crucial areas such as pediatric rehabilitation and long-term disease care in AI physiotherapy research.

It is necessary for future studies to address these structural shortcomings by promoting intersdisciplinary collaboration among computer science, physiotherapy, geriatrics, and pediatrics to develop more integrated AI applications.

4.2.6. *Trend topics*

The line graph in Fig. 24 depicts the growth and decline of trending research subjects over time, showing the increased and decreased interest over various domains. Consistent growth is evident for terms such as "artificial intelligence," "human," "physiotherapy," and "machine learning," especially from 2020 to 2023, indicating their growing significance in interdisciplinary research fields. Conversely, words like "spondylolisthesis" and "equipment design" are episodically prominent earlier in the timeline but have decreased in recent years, indicating a move away from condition-specific or hardware-focused studies.

The continued prominence of "robotics" and "virtual reality" since 2018 indicates the increasing impact of assistive and immersive technologies on physiotherapy practice. Yet, even special topics such as "decision support systems," "neurorehabilitation," and "adolescent" lag behind, uncovering structural deficits in AI applications supporting real-

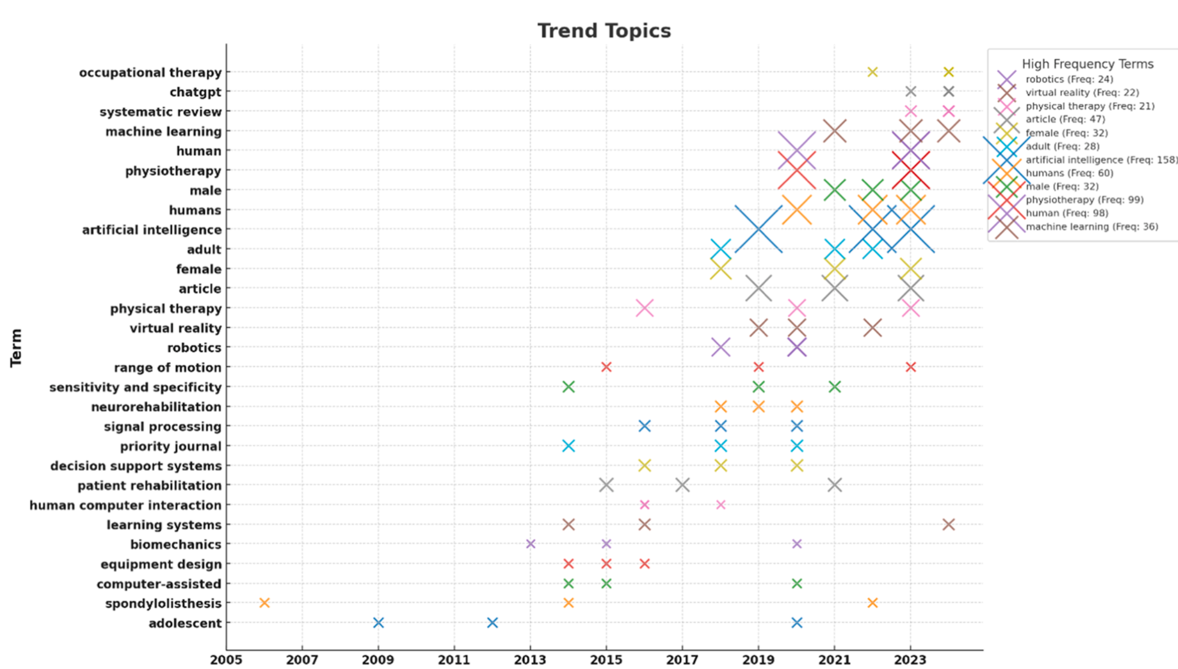

Fig. 24. Trend topics.

time clinical decision-making and pediatric rehabilitation. This pattern indicates that future priorities should continue to pursue bringing AI tools more seamlessly into decision-support structures and broadening therapeutic innovations towards currently underrepresented patient populations in order to have greater clinical impact.

4.2.7. The thematic evolution

Fig. 25 displays the thematic trend of research themes from 2006–2022–2023–2024, emphasizing how essential themes have changed or broadened. "Artificial intelligence," "systematic review," and "bibliometrics" have persisted, suggesting ongoing interest in computational approaches and systematic research synthesis. New highlighted themes like "exercise," "virtual reality," and "digital health" reflect an increased convergence between AI and pragmatic, patient-focused rehabilitation strategies. In contrast, standard clinical emphases such as "low back pain" and "assessment" continue but demonstrate fairly stable thematic interconnectedness, consistent with steady though slower innovation. The modest crossover of themes from domains such as "multiple sclerosis" and "elderly" into emerging topics implies shortcomings in applying AI tools to at-risk groups. Future studies should work towards enhancing integration among clinical fields and new digital health paradigms to make progress in AI translate into wider and more varied patient populations.

4.2.8. Collaboration networks

Figs. 26, 27, and 28 show the networks of collaboration between authors, institutions, and countries respectively, and the global interconnectedness of AI and physiotherapy research.

The highly connected nodes like Buckley E, Alcock L, and Niessen M (authors), the University of Bologna and University College London (institutions), and the USA, UK, and Germany (countries) have high centrality, reflecting their dominance in driving research agendas. Dense clustering among European and Nordic countries indicates strong regional cooperation, while emerging bilateral collaborations between China, India, and Western institutions suggest shifting dynamics toward a more globally distributed research environment. However, peripheral nodes with weaker linkages point toward barriers such as limited international engagement from developing countries and smaller universities. This unbalanced collaboration environment underscores the necessity for future efforts towards creating inclusivity by facilitating cross-regional collaborations, especially with underrepresented regions, to increase global knowledge exchange and innovation in AI-based physiotherapy.

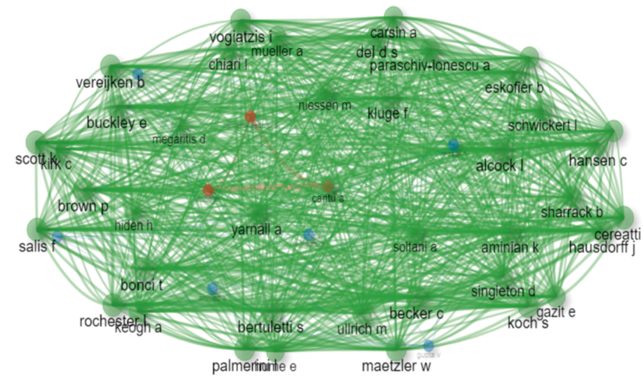

Fig. 26. Authors' collaboration network.

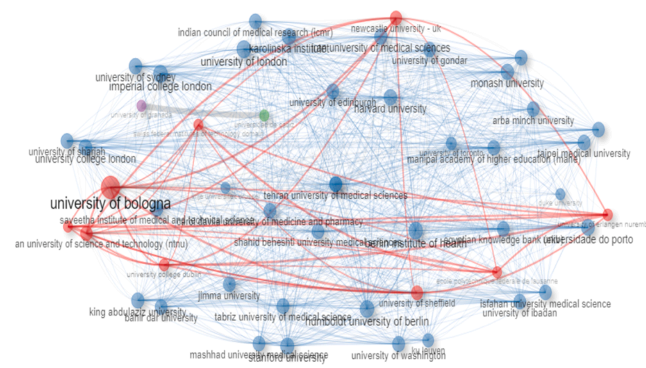

Fig. 27. Institute collaboration network.

5. Discussion

RQ 1: What are the descriptive statistics and development

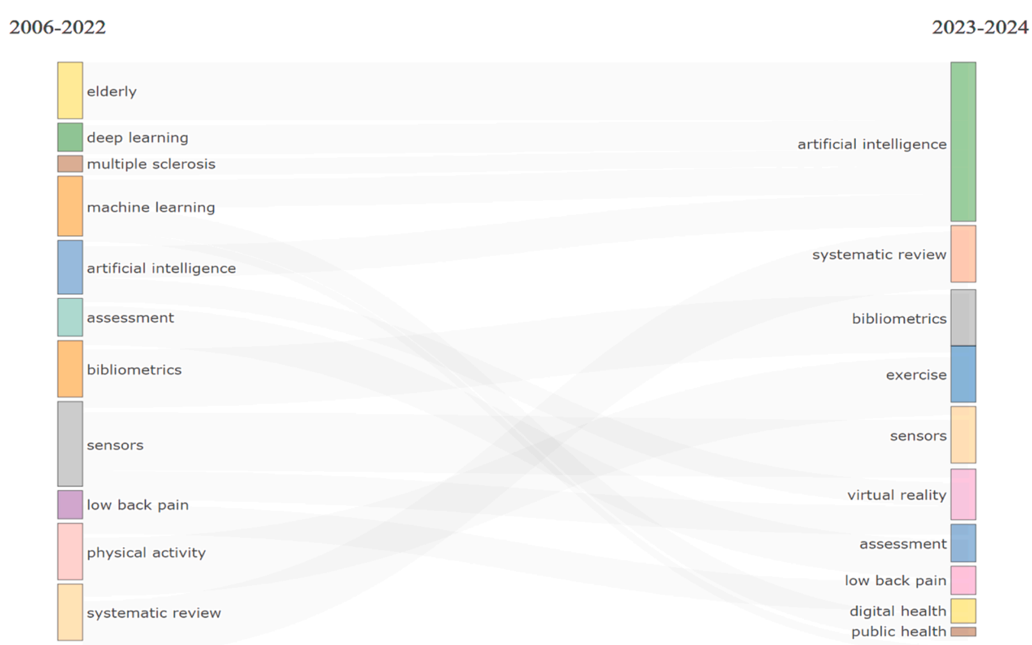

Fig. 25. The thematic evolution.

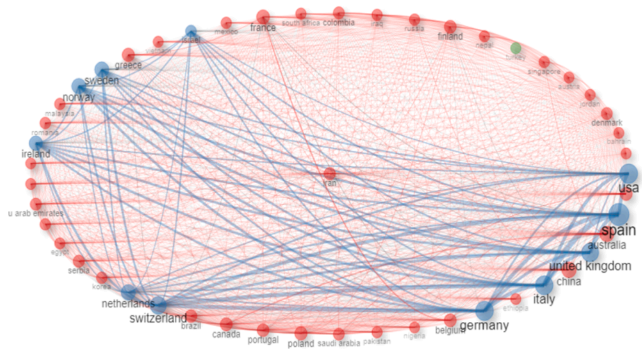

Fig. 28. Country collaboration network.

trends in AI and physiotherapy research?

The bibliometric analysis of AI and physiotherapy research from 2006 to 2024 demonstrates a significant upward trajectory, with a 15.9 % increase in research output, reflecting the burgeoning interest in this interdisciplinary domain. The findings underscore the increasingly collaborative nature of this field, with a 25.59 % rate of international co-authorship and an average of 13.3 authors per document. Such patterns highlight the inherently interdisciplinary characteristics of AI and physiotherapy research, necessitating diverse expertise to address its multifaceted challenges effectively.

It can be seen from spatial statistics that the most significant portion of global research is concentrated in North America, Europe, and most of Asia, where key players are reputed institutions like the Tehran University of Medical Sciences and some of the notable universities in the United States. The data exposes a massive gap between these regions and the rest of the world. For instance, many less-developed regions, such as Africa, South America, and the Middle East, contribute little to scientific delivery. These deficits' origins lie in the social marginalization of regions subjected to a historical development path that does not have the perspective of developed countries such as the USA. If this social order persists even as AI segues into healthcare, equal healthcare services will inevitably not be available to all.

The study examined the issue of AI in health services, problems concerning the division of digital resources, and possible solutions. It included a detailed description of AI applications in health services, discussions about the availability of skilled personnel, and arguments on the importance of teamwork in the success of AI-based solutions in health care. Considering that regions like North America, Europe, and Asia with high incomes enjoy the state of technology advancements, well-established funding systems, research institutions with the latest research providers, and policy frameworks that encourage the integration of AI in health services, on the contrary, resource-limited areas such as Africa, South America and few parts of Middle East must contend with the same persistent problems. These include limited access to computing power, lack of qualified researchers, and very little inter-discipline collaboration. The digital divide restricts inputs from these areas to the scientific dialogue and inhibits their capacity to develop and use AI technologies in such clinical and medical rehabilitation contexts. Rapid collaboration amongst international entities, targeted investments in capacity-building, and initiatives to provide equitable access to AI-driven novel solutions in physiotherapy, like musician traumatology, are needed to engender these disparities.

Aside from infrastructural constraints, regional differences in AI uptake in physiotherapy can also be explained by geopolitical factors. Differences in national priorities for research funding, data governance, and regulatory frameworks significantly affect the ability of various regions to innovate and collaborate in AI-powered healthcare. For example, strict data privacy regulations in the EU under GDPR, as opposed to more permissive data environments in other parts of the world, influence the training and deployment of AI systems. In addition, few cross-border technology transfer agreements and sanctions tend to limit the free flow of AI-related innovations to developing nations. These structural problems need to be solved through global partnerships, coordinated regulatory policies, and comprehensive global health programs to support balanced AI development in physiotherapy and rehabilitation sciences.

In addition to the descriptive identification of regional inequalities, there is a need to recognize underlying structural determinants of the imbalanced use of AI in physiotherapy. Geopolitical tensions tend to constrain data-sharing partnerships between nations, whereas infrastructural deficits, including poor internet connectivity and restricted wearable technology access, greatly hinder AI-based rehabilitation interventions in developing countries. Additionally, linguistic and cultural differences affect the creation and implementation of AI algorithms, which tend to be trained primarily on English-language datasets. These barriers underscore that closing technological gaps alone is not enough; inclusive policymaking, localized AI training datasets, and cross-border research collaborations are essential to ensuring equitable integration of AI innovations into global physiotherapy practices.

RQ 2: How has publication activity in AI and physiotherapy evolved over time?

Publication activity in AI and physiotherapy has shown a steady rise until 2018, followed by a notable surge from 2019 to 2022. This increase likely reflects pivotal advancements in AI technologies and their growing application in physiotherapy practices. However, the slight decline observed in 2023 and 2024 may indicate potential shifts in research focus or market dynamics. The citation patterns during this period display variability, with peaks and troughs suggesting that certain publications have had a more significant impact than others. This uneven impact could be attributed to seminal works or influential reviews that have shaped the discourse in this field.

RQ 3: How has scientific mapping in AI and physiotherapy changed in recent decades?

Scientific mapping of the AI and physiotherapy field shows a clear evolution in research focus over the past decades. The analysis identifies influential journals such as *SENSORS* and *APPLIED SCIENCES-BASEL* as central to the dissemination of key research findings. The h-index analysis underscores the impact of specific authors and journals in shaping the field, with prominent contributors such as Rahman M and Herrera-Viedma E playing significant roles. Thematic evolution reveals a shift towards more advanced AI applications, with increasing emphasis on machine learning and artificial intelligence in recent years, while earlier topics such as spondylolisthesis have declined in prominence. The emergence of new research themes and the expansion of collaborative networks reflect the dynamic nature of this field.

RQ 4: What are the recent trends and changes in AI and physiotherapy research?

Artificial intelligence (AI) and physiotherapy are significantly improving with the application of new technologies in rehabilitation therapy, such as telerehabilitation, control of tissues after therapy, wearables, and robotics for treatment. With these emerging technologies, the strategy provides the opportunity for a different method of therapy and adds patient follow-up and compliance with innovative paths that can be taken that have never been used before. Especially, the COVID-19 pandemic has been a key reason for this integration, accelerating the process of creating AI-led solutions to fill the gap in healthcare services that are both remote and instant, thus being able to be more accessible and efficient in them. Therefore, the adoption of these technologies is not a passing trend but rather the one-way road to a more productive and patient-centric healthcare delivery.

5.1. Telerehabilitation: advancing remote therapy

Telerehabilitation is gaining prominence as a low-cost, accessible physiotherapy service delivery method. The integration of artificial intelligence in telerehabilitation systems has improved functionality such that the following has become possible:

- Real-Time Monitoring and Feedback. AI algorithms, in combination with motion sensors and cameras, provide instantaneous real-time feedback to both therapists and patients. Gait patterns can be analyzed on a machine learning level, allowing therapists to tailor interventions more appropriately and dynamically.[45]
- Personalized Therapeutic Interventions: AI-based telerehabilitation systems can provide personalized therapy plans based on patient progress and adherence data, greatly improving treatment outcomes by Development of Robot-Assisted Telerehabilitation Systems.[46]
- Interactive Virtual Therapists: AI-powered virtual assistants are used by the patients to have instructors for the correct exercises and ensure that they perform the exercises as told by the therapist and adhere to the regimen.[47]

Some of the most recent studies, including digital twins and IoT, show the business potential of communication technologies. These technologies are adequate for creating hyper-personalized rehabilitation experiences and monitoring the patient progression in real-time and remotely by the Development of Robot-Assist Telerehabilitation Systems with Integrated IoT and Digital Twin.[48]

5.1.1. Wearable devices: precision in monitoring

With wearable devices, the delivery and administration of physiotherapy have been significantly changed. Information on how patients move or the proper functioning of the muscles is collected accurately with tools equipped with inertial measurement units (IMUs), EMG sensors, and pressure sensors. Artificial intelligence integration is increasingly implemented for these devices because

- Improving Diagnostic Precision: Artificial intelligence algorithms analyze data obtained from wearable sensors to detect abnormalities in movement and forecast possible complications.[49]
- Monitor Rehabilitation Progress: Wearable technologies provide patients with constant data streams to increase their long-term monitoring and the effectiveness of their therapy programs.[50]
- Improve Patient Engagement: Real-time feedback from wearables motivates patients to comply fully with their rehabilitation regimens. For example, some biofeedback-based wearables vibrate or beep whenever incorrect movements are detected.[51]

Studies have proved that using wearable devices in combination with telerehabilitation platforms finally results in the user's real-time monitoring and correction as well as immediate feedback by a Mechatronic System for Robot-Mediated Hand Telerehabilitation.[52]

5.1.2. Robotics: automating and enhancing therapy

In physiotherapy, repeated and precise movements have been made effective through robotics. Thereby, AI could facilitate and enhance their appropriateness in robotic systems by providing the following:

- Robotic-assisted rehabilitation involves robotic devices, including exoskeletons and manipulators, which provide controlled assistance, mainly to restore mobility and strength in patients who have suffered from motor deficits following injuries.[53]
- Adaptive Control Mechanisms: AI-adaptive control changes, at the most, the levels of robot assistance according to what the patient accomplishes or fails to accomplish for optimal engagement and recovery by Review of Control Methods for Upper Limb Telerehabilitation with Robotic Exoskeletons.[54]
- Telerehabilitation Robots: These devices use sensors and artificial-intelligence algorithms to monitor and interact remotely with patients during therapy sessions, thereby crossing geographical barriers in care.[55]

Other products of rehabilitation such as hand exoskeletons combined with mechatronic designs effectively meet the rehabilitation needs of fine motor skills. They exhibit dynamic adaptation according to progressing levels of resistance and find their best utility in stroke recovery.[56]

Recent real-world applications of AI in physiotherapy demonstrate promising clinical outcomes. For example, in post-stroke rehabilitation, AI-powered exoskeletons equipped with adaptive gait analysis systems have been used to support patient mobility training. These systems continuously analyze joint angles, step length, and balance metrics to adjust assistance levels in real time, thereby improving functional recovery and reducing therapist burden. Similarly, machine learning algorithms integrated with motion sensors have been applied in patients with Parkinson's disease to detect and correct freezing of gait episodes through real-time vibrotactile feedback. Such AI-driven interventions not only enhance therapeutic precision but also expand the reach of physiotherapy services to home-based settings.

AI and physiotherapy research reflects growing global collaboration. Key nodes of research activity are in the United States, Europe, and parts of Asia, with institutions like Tehran University of Medical Sciences playing a pivotal role. Research on AI applications in physiotherapy is increasingly interdisciplinary, involving collaboration among engineers, clinicians, and data scientists to develop advanced systems that address specific therapeutic challenges. Emerging collaborations aim to bridge gaps in healthcare accessibility, particularly through scalable and cost-effective AI solutions.

RQ 5: What are the future research directions in AI and physiotherapy?

The future of AI and physiotherapy research lies in several key areas:

1. **Integration of Advanced AI Techniques in Physiotherapy:** Future research should focus on integrating more sophisticated AI techniques, such as deep learning and neural networks, into physiotherapy practices. These advancements could lead to more personalized treatment plans, improved patient outcomes, and streamlined rehabilitation processes. Research should explore how these technologies can be applied to real-time monitoring and adaptive therapy, addressing challenges related to data privacy, algorithmic transparency, and patient compliance.
2. **Expansion of Collaborative Research Networks:** To overcome regional disparities in research output, future studies should aim to expand collaborative networks, particularly by fostering partnerships between institutions in underrepresented regions. This would help diversify research perspectives, address region-specific health challenges, and promote the development of AI-driven physiotherapy solutions tailored to different cultural and healthcare contexts.
3. **Focus on Emerging Technologies:** As technologies such as telerehabilitation, virtual reality, and robotics gain prominence, future research should delve deeper into these areas, exploring how they can be effectively integrated with AI to enhance remote therapy and provide innovative rehabilitation tools. Studies on the long-term efficacy, accessibility, and cost-effectiveness of these technologies will be crucial to their widespread adoption.
4. **Ethical and Societal Implications of AI in Physiotherapy:** Because of the surge in AI use in physiotherapy, especially concerning its ethical and societal implications, it is time to formulate proactive measures for preemptive action.[57] While AI technologies promise a great deal in transforming the physiotherapy field, issues about data privacy, algorithmic bias, and autonomy of patient-doctor relationships have come to the fore since they raise many fundamental questions. AI systems process sensitive patient data; thus, strict sector-relevant regulation, encryption technologies, and transparent actions could enhance a general sense of trust. Such algorithmic bias could raise alarms for unfair patient treatment, notions associated with fairness, particularly those relating to poorly

resourced regions, must include collaborative play frameworks on a global scale and representative datasets. Ethical guides should respect patient autonomy with informed consent and allow the patient a definitive awareness of AI's role in their care. However, preserving the therapy-doctor-patient relationship must hold ground; the assistive model whereby AI aids but does not replace clinicians is arguably the only ethical model. Sociocultural contexts are critical as they introduce an additional layer of complexity hence, developing culturally adaptive frameworks is necessary to adequately tackle a full range of ethical challenges. This medication theoretically enables the transition into mechanized physiotherapy that improves the precision of the human body, it also raises other challenges like demographic inequality and accessibility issues, which fuel broad efforts around bridging the digital divide. In the first instance, the overarching ethical framework for integrating AI into physiotherapy must address transparency, implement accountability mechanisms, encourage international collaboration on ethical guidelines, and promote societal inclusion.

5. **Evaluation of AI-Driven Outcomes in Diverse Populations:** Future studies should evaluate the effectiveness of AI-driven physiotherapy interventions across different demographic groups, including varied age groups, genders, and ethnicities. This would ensure that AI applications in physiotherapy are inclusive and beneficial for all patients, regardless of their background.
6. **Longitudinal Studies on AI Impact:** Given the recent surge in AI-related physiotherapy research, there is a need for longitudinal studies to assess the long-term impact of AI technologies on patient outcomes, therapy processes, and healthcare systems. Such studies would provide valuable insights into the sustainability, scalability, and overall effectiveness of AI interventions in physiotherapy, guiding future innovations and policy developments in this field.

By pursuing these research directions, the field of AI and physiotherapy can continue to grow, addressing current challenges while exploring new opportunities to enhance patient care through technological innovation.

5.1.3. Future research directions

The prospects of the future of integrating artificial intelligence (AI) in physiotherapy are a rich potential for enriching rehabilitation science, enhancing the outcome of the patient, and fulfilling crucial knowledge gaps.

1. **Systematic Assessment of AI Technologies:** There needs to be greater depth, specifically critical reviews, of existing bibliometric generalizations of different AI technologies that should be looked at in a particular context, like in physiotherapy. Issues such as model overfitting, reduced interpretability, and clinical safety concerns like algorithmic bias need to be thoroughly evaluated. The use of sophisticated methods like topic modeling (e.g., Latent Dirichlet Allocation) and structured comparative analysis would improve the technical quality of subsequent studies.
2. **Broadening Thematic Depth and Clinical Relevance:** Research needs to be extended to unexplored areas such as pediatric rehabilitation, neurorehabilitation, musculoskeletal disorders, and geriatric care. Interventions based on AI need to be proven through longitudinal and randomized controlled trials to establish their effectiveness in the real world, especially among vulnerable patients in need of customized rehabilitation strategies.
3. **Ethical Foundations and Explainability:** To enable responsible AI integration, upcoming research should incorporate elements of international ethical frameworks like the WHO's AI Ethics Guidelines and AI4People's proposals. Utilizing explainable AI (XAI) tools, handling demographic biases, maintaining data privacy in remote treatments like telerehabilitation, and enhancing transparency in all AI systems will be critical for trust and inclusivity.
4. **Fostering Global Research Parities in Collaboration:** As the profound regional disparities reflected in recent research publications are indicated, future planning has to enhance cross-regional collaboration, capacity-building initiatives, and the establishment of open-source AI tools responsive to low- and middle-income countries. Such efforts will bridge infrastructural gaps and promote globally representative innovation.
5. **Incorporating Advanced Technologies into Rehabilitation Practice:** There is enormous potential in incorporating AI with complementary technologies like virtual reality (VR), augmented reality (AR), digital twins, and Internet of Things (IoT) devices to provide hyper-personalized rehabilitation experiences. In addition, robotics with AI-tunable control mechanisms have the potential to transform physical therapy, providing adaptive responses to unique patient trajectories.
6. **Increasing Methodological Sophistication in Scientometric Research:** Future bibliometric analysis must employ advanced analytical techniques, such as betweenness centrality, modularity class detection, citation burst analysis, and normalized citation density measures. Shifting from metadata-only research to full-text searching will provide more comprehensive, precise data on AI-physiotherapy knowledge patterns.
7. **Quantification of Long-Term Effect and Cost-Effectiveness:** Longitudinal quantification will be necessary to measure the long-term effect of AI-driven physiotherapy treatment on patient rehabilitation, quality of care, and cost-effectiveness. Studies should focus on long-term adherence by patients, efficiency in optimizing therapists' workloads, and improvement in functional and quality-of-life measures to determine the extrapolated societal benefit of AI implementation in rehabilitation sciences.

In conclusion, the way forward for AI in physiotherapy needs a world-inclusive, ethics-oriented, and multidisciplinary research agenda. Through the promotion of critical assessments of new technologies, tackling global inequalities, integrating explainable and responsible AI paradigms, and rigorously testing clinical effects, the discipline can break free from innovation for innovation's sake to deliver meaningful, patient-focused change. Collaboration between clinicians, engineers, policymakers, and researchers from various regions will be essential to make AI-based physiotherapy solutions equitable, accessible, and effective for all populations. A collective focus on methodological rigor, ethical foresight, and technological integration will characterize the next generation of impactful and sustainable innovations in AI-facilitated rehabilitation sciences.

6. Conclusion

The bibliometric analysis of AI and physiotherapy research from 2006 to 2024 offers a comprehensive overview of the field's development, key contributors, and emerging trends. The study reveals significant growth in research output, driven by the increasing integration of AI technologies into physiotherapy practices under the public health sector. Key journals, authors, and institutions have played pivotal roles in advancing the field, while collaborative networks have predominantly concentrated in North America, Europe, and Asia. Thematic analysis highlights the prominence of AI and machine learning as central to recent research, with growing interest in related technologies such as telerehabilitation and robotics.

The findings underscore the interdisciplinary nature of AI and physiotherapy among the public health domain, demonstrating how these fields are converging to create innovative therapeutic solutions. However, the study also identifies areas that require further exploration, such as the need for more diverse global collaborations, ethical considerations in AI deployment, and the evaluation of AI-driven interventions across varied populations. By addressing these gaps and building on the current body of knowledge, future research can further enhance the role of AI in physiotherapy, ultimately leading to improved patient outcomes and more efficient healthcare delivery. The study thus provides a foundational understanding of the current landscape, while also setting the stage for future advancements in this rapidly evolving field.

CRediT authorship contribution statement

Basil Hanafi: Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ahmad Hasan**: Visualization, Supervision, Software, Resources, Project administration. **Anas Ahmad**: Writing – review & editing, Writing – original draft, Validation. **Mohammad Ali**: Writing – review & editing, Writing – original draft, Visualization, Software.

Funding

No Funding Provided for this Research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

Data Set is available on request.

References

[1]. M. Jabarulla, H. L.- Healthcare, and undefined 2021, "A blockchain and artificial intelligence-based, patient-centric healthcare system for combating the COVID-19 pandemic: Opportunities and applications," *mdpi.com*, Accessed: Aug. 27, 2024. [Online]. Available: ⟨https://www.mdpi.com/2227-9032/9/8/1019⟩.

[2]. Y. Yang, H. Wang, C. Ji, and Y. Niu, "Artificial Intelligence-Driven Diagnostic Systems for Early Detection of Diabetic Retinopathy: Integrating Retinal Imaging and Clinical Data," vol. 2023, pp. 83–90, Jul. 2023, Accessed: Apr. 29, 2025. [Online]. Available: https://doi.org/10.70470/SHIFAA/2023/010.

[3]. AlSajri AA, Hariry N. The future of surgery: robotic-assisted procedures and their impact (vol) *SHIFAA*. 2024;2024:52–55. https://doi.org/10.70470/SHIFAA/2024/006.

[4]. Al-Masroub RM, Fiadh MS. Minimal prime and semiprime submodules (vol) *Babylon J Math*. 2023;2023:84–87. https://doi.org/10.58496/bjm/2023/016.

[5]. Söderlund A. Artificial intelligence and physiotherapy–editorial. *Eur J Physiother*. Jan. 2019;21(1):1. https://doi.org/10.1080/21679169.2019.1569850.

[6]. Albahrouh SI, Buabbas AJ. Physiotherapists' perceptions of and willingness to use telerehabilitation in Kuwait during the COVID-19 pandemic. *BMC Med Inf Decis Mak*. Dec. 2021;21(1). https://doi.org/10.1186/S12911-021-01478-X.

[7]. S. Baidya, V. K.-R. T. in M. Research. New, and undefined 2022, "Extent of Artificial Intelligence in Physiotherapy," *researchgate.net*, Accessed: Aug. 27, 2024. [Online]. Available: ⟨https://www.researchgate.net/profile/Shalaka-Baidya/publication/364603497_Chapter_-4_Extent_of_Artificial_Intelligence_in_Physiotherapy_Chapter_-4_Extent_of_Artificial_Intelligence_in_Physiotherapy/links/6352aa4b6e0d367d91b27d10/Chapter-4-Extent-of-Artificial-Intelligence-in-Physiotherapy-Chapter-4-Extent-of-Artificial-Intelligence-in-Physiotherapy.pdf⟩.

[8]. J. Davids, N. Lidströmer, H. A.-A. I. in Medicine, and undefined 2022, "Artificial Intelligence for Physiotherapy and Rehabilitation," *Springer*, Accessed: Aug. 27, 2024. [Online]. Available: ⟨https://link.springer.com/content/pdf/10.1007/978-3-030-64573-1_339.pdf⟩.

[9]. Boyer P, Burns D, Whyne C. Evaluation of at-home physiotherapy machine-learning prediction with smart watch inertial sensors. *Bone Jt Res*. Mar. 2023;12(3):165–177. https://doi.org/10.1302/2046-3758.123.BJR-2022-0126.R1.

[10]. Abed SA, Khalil ZH. Reliability allocation in complex systems using fuzzy logic modules (vol) *Babylon J Math*. 2023;2023:78–83. https://doi.org/10.58496/bjm/2023/015.

[11]. Russell TG, Blumke R, Richardson B, Truter P. Telerehabilitation mediated physiotherapy assessment of ankle disorders. *Physiother Res Int*. Sep. 2010;15(3):167–175. https://doi.org/10.1002/PRI.471.

[12]. Richardson BPhty BR, Truter MPhty P, Blumke BPhty R, Russell BPhty TG. Physiotherapy assessment and diagnosis of musculoskeletal disorders of the knee via telerehabilitation. *J sagepub Com*. Jan. 2017;23(1):88–95. https://doi.org/10.1177/1357633X15627237.

[13]. Sidiq M, Chahal A, Gupta S, K. V.- Interdisciplinary, and undefined. Advancement, utilization, and future outlook of Artificial Intelligence for physiotherapy clinical trials in India: an overview. *ri ageditor Ar*. 2024;2023. https://doi.org/10.56294/ri202473.

[14]. Mensah GB, et al. Explainable AI for healthcare: training healthcare workers to use artificial intelligence techniques to reduce medical negligence in Ghana's Public Health Act, 2012 (Act 851) (vol) *EDRAAK*. 2025:1–6. https://doi.org/10.70470/EDRAAK/2025/001.

[15]. R. Aziz, H. Sundus, … F. J.-R. T. in, and undefined 2023, "Embracing technological innovations: the integration of AI in physiotherapy," *researchgate.net*, vol. 9, Accessed: Aug. 27, 2024. [Online]. Available: ⟨https://www.researchgate.net/profile/Habiba-Sundus/publication/375422312_EMBRACING_TECHNOLOGICAL_INNOVATIONS_THE_INTEGRATION_OF_AI_IN_PHYSIOTHERAPY/links/6549e3e4b1398a779d6bcc21/EMBRACING-TECHNOLOGICAL-INNOVATIONS-THE-INTEGRATION-OF-AI-IN-PHYSIOTHERAPY.pdf⟩.

[16]. Hanafi B, Ali M, Singh D. Quantum algorithms for enhanced educational technologies. *Discov Educ*. 2025;4(1). https://doi.org/10.1007/s44217-025-00400-1.

[17]. Kumar S, Sharma A, Rishi P. Importance and uses of telemedicine in physiotherapeutic healthcare system: a scoping systemic review. *Lect Notes Netw Syst*. 2022;238:411–422. https://doi.org/10.1007/978-981-16-2641-8_39.

[18]. N. Donthu, S. Kumar, D. Mukherjee, … N. P.-J. of business, and undefined 2021, "How to conduct a bibliometric analysis: An overview and guidelines," *Elsevier*, vol. 133, pp. 285–296, 2021, doi: 10.1016/j.jbusres.2021.04.070.

[19]. Raza A, Qadri AM, Akhtar I, Samee NA, Alabdulhafith M. LogRF: an approach to human pose estimation using skeleton landmarks for physiotherapy fitness exercise correction. *IEEE Access*. 2023;11:107930–107939. https://doi.org/10.1109/ACCESS.2023.3320144.

[20]. Çubukçu B, Yüzgeç U. Shoulder rehabilitation: a neuro-fuzzy inference approach to recovery prediction. *Neural Comput Appl*. 2023;35(26):18891–18903. https://doi.org/10.1007/S00521-023-08713-8.

[21]. B. Kiran, D. Thomas, R. P.-J. of Imaging, and undefined 2018, "An overview of deep learning based methods for unsupervised and semi-supervised anomaly detection in videos," *mdpi.com*, Accessed: Aug. 13, 2024. [Online]. Available: ⟨https://www.mdpi.com/2313-433X/4/2/36⟩.

[22]. C. T.-M. S. and Practice and undefined 2019, "Artificial intelligence and machine learning| applications in musculoskeletal physiotherapy," *Elsevier*, Accessed: Aug. 28, 2024. [Online]. Available: ⟨https://www.sciencedirect.com/science/article/pii/S2468781218301590⟩.

[23]. J. DeFrank, A. L.-J. of Carcinogenesis, and 2022, "AI-based personalized treatment recommendation for cancer patients," submissions.carcinogenesis.comJ DeFrank, A LuizJournal of Carcinogenesis, 2022•submissions.carcinogenesis.com, 2022, doi: 10.4103/jcar.jcar_21_02_08.

[24]. F. Al-Akayleh, … M. A.-R.-2024 2nd I., and undefined 2024, "AI-Driven Physical Rehabilitation Strategies in Post-Cancer Care," *ieeexplore.ieee.org*, Accessed: Aug. 29, 2024. [Online]. Available: ⟨https://ieeexplore.ieee.org/abstract/document/10532883/⟩.

[25]. J. Oyeniyi and P. Oluwaseyi, "Emerging Trends in AI-Powered Medical Imaging: Enhancing Diagnostic Accuracy and Treatment Decisions," *researchgate.net*, Accessed: Aug. 29, 2024. [Online]. Available: ⟨https://www.researchgate.net/profile/Johnson-Oyeniyi/publication/379898576_Emerging_Trends_in_AI-Powered_Medical_Imaging_Enhancing_Diagnostic_Accuracy_and_Treatment_Decisions/links/6620e2ac66ba7e2359e64373/Emerging-Trends-in-AI-Powered-Medical-Imaging-Enhancing-Diagnostic-Accuracy-and-Treatment-Decisions.pdf⟩.

[26]. Van Egmond MA, et al. Effectiveness of physiotherapy with telerehabilitation in surgical patients: a systematic review and meta-analysis. *Elsevier*. 2018;104:277–298. https://doi.org/10.1016/j.physio.2018.04.004.

[27]. A. Deoskar, S. Parab, and S. Patil, "PERSONALIZED PHYSIO-CARE SYSTEM USING AI," Handbook of Research on Artificial Intelligence and Soft Computing Techniques in Personalized Healthcare Services, pp. 229–258, Jan. 2024, doi: 10.1201/9781003371250-13/PERSONALIZED-PHYSIO-CARE-SYSTEM-USING-AI-ARUNA-DEOSKAR-SHILPA-PARAB-SHUBHANGI-PATIL.

[28]. S. Junaid, A. Imam, M. Abdulkarim, Y. S.-A. Sciences, and undefined 2022, "Recent advances in artificial intelligence and wearable sensors in healthcare delivery," *mdpi.com*, Accessed: Aug. 29, 2024. [Online]. Available: ⟨https://www.mdpi.com/2076-3417/12/20/10271⟩.

[29]. Rehman S, Hasan A, Singh V, Almaqtari FA. Decoding the complex relation of financial development and carbon emission using bibliometric analysis. *Cogent Bus Manag*. 2024;11(1). https://doi.org/10.1080/23311975.2023.2294524.

[30]. J. A.- Boston, undefined MA, and undefined 2012, RStudio: integrated development environment for R, *academia.eduJ AllaireBoston, MA, 2012•academia.edu*, Accessed: Jul. 23, 2024. [Online]. Available: ⟨https://www.academia.edu/download/49999670/IntR_-_Interactive_GUI_for_R20161031-11791-s0u02o.pdf#page= 14⟩.

[31]. A. P.-J. of documentation and undefined 1969, Statistical bibliography or bibliometrics, *cir.nii.ac.jp*, Accessed: Aug. 13, 2024. [Online]. Available: ⟨https://cir.nii.ac.jp/crid/1570009750342049664⟩.

[32]. J. Merigó, A. Mas-Tur, … N. R.-T.-J. of B., and undefined 2015, "A bibliometric overview of the Journal of Business Research between 1973 and 2014," *Elsevier*, vol. 68, pp. 2645–2653, 2015, doi: 10.1016/j.jbusres.2015.04.006.

[33]. Hanafi B, Ali M. Analyzing the research impact in post quantum cryptography through scientometric evaluation. *Discov Comput*. 2025;28(1):32. https://doi.org/10.1007/s10791-025-09507-3.

[34]. H.B. Fuentes and J.C. Katchadourian, A bibliometric overview of the international journal of interactive multimedia and artificial intelligence, 2018, Accessed: Aug. 31, 2024. [Online]. Available: ⟨https://digibug.ugr.es/handle/10481/64931⟩.

[35]. D. Mukherjee, W. Lim, S. Kumar, N. D.-J. of business research, and undefined 2022, "Guidelines for advancing theory and practice through bibliometric research," *Elsevier*, Accessed: Aug. 31, 2024. [Online]. Available: ⟨https://www.sciencedirect.com/science/article/pii/S0148296322003824⟩.

[36]. Broadus RN. Toward a definition of 'bibliometrics. *Scientometrics*. 1987;12(5–6):373–379. https://doi.org/10.1007/BF02016680.
[37]. Zupic I, Čater T. Bibliometric methods in management and organization. *Organ Res Methods*. 2015;18(3):429–472. https://doi.org/10.1177/1094428114562629.
[38]. Abed SA, et al. Application of the Jaya algorithm to solve the optimal reliability allocation for reduction oxygen supply system of a spacecraft. *Indones J Electr Eng Comput Sci*. 2021;24(2):1202–1211. https://doi.org/10.11591/ijeecs.v24.i2.pp1202-1211.
[39]. N. Donthu, S. Kumar, D. Mukherjee, … N. P.-J. of business, and undefined 2021, "How to conduct a bibliometric analysis: An overview and guidelines," *Elsevier*, Accessed: Jul. 23, 2024. [Online]. Available: ⟨https://www.sciencedirect.com/science/article/pii/S0148296321003155⟩.
[40]. N. Ameen, G.Deep Sharma, S. Tarba, A. Rao, R. Chopra, and R. Holloway, "Toward advancing theory on creativity in marketing and artificial intelligence," Wiley Online LibraryN Ameen, GD Sharma, S Tarba, A Rao, R ChopraPsychology & marketing, 2022 Wiley Online Library, vol. 39, no. 9, pp. 1802–1825, Sep. 2022, doi: 10.1002/mar.21699.
[41]. Bilro RG, Loureiro SMC. A consumer engagement systematic review: synthesis and research agenda. *Span J Mark - ESIC*. 2020;24(3):283–307. https://doi.org/10.1108/SJME-01-2020-0021/FULL/.
[42]. Dawkins E, André K, Axelsson K, Benoist L, Swartling ÅG, Persson Å. Advancing sustainable consumption at the local government level: a literature review. *J Clean Prod*. 2019;231:1450–1462. https://doi.org/10.1016/J.JCLEPRO.2019.05.176.
[43]. Mariani M, Baggio R, Fuchs M, Höepken W. Business intelligence and big data in hospitality and tourism: a systematic literature review. *Int J Contemp Hosp Manag*. 2018;30(12):3514–3554. https://doi.org/10.1108/IJCHM-07-2017-0461/FULL/HTML.
[44]. Haddaway NR, Page MJ, Pritchard CC, McGuinness LA. PRISMA2020: an R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Syst Rev*. 2022;18(2), e1230. https://doi.org/10.1002/cl2.1230.
[45]. Seron P, et al. *Effectiveness of Telerehabilitation in Physical Therapy: A Rapid Overview*. Jun. 01. Oxford University Press; 2021. https://doi.org/10.1093/ptj/pzab053.
[46]. Nuara A, Fabbri-Destro M, Scalona E, Lenzi SE, Rizzolatti G, Avanzini P. *Telerehabilitation in response to constrained physical distance: An opportunity to rethink neurorehabilitative routines*. Feb. 01. Springer Science and Business Media Deutschland GmbH; 2022. https://doi.org/10.1007/s00415-021-10397-w.
[47]. Liu Y, Guo S, Yang Z, Hirata H, Tamiya T. A home-based tele-rehabilitation system with enhanced therapist-patient remote interaction: a feasibility study. *IEEE J Biomed Health Inf*. 2022;26(8):4176–4186. https://doi.org/10.1109/JBHI.2022.3176276.
[48]. Hesse S, Waldner A, Mehrholz J, Tomelleri C, Pohl M, Werner C. Combined transcranial direct current stimulation and robot-assisted arm training in subacute stroke patients: an exploratory, randomized multicenter trial. *Neurorehabil Neural Repair*. 2011;25(9):838–846. https://doi.org/10.1177/1545968311413906.
[49]. Jeong IC, Bychkov D, Searson PC. Wearable devices for precision medicine and health state monitoring. *IEEE Trans Biomed Eng*. 2019;66(5):1242–1258. https://doi.org/10.1109/TBME.2018.2871638.
[50]. R. De Fazio, V.M. Mastronardi, M. De Vittorio, and P. Visconti, "Wearable Sensors and Smart Devices to Monitor Rehabilitation Parameters and Sports Performance: An Overview," Feb. 01, 2023, MDPI. doi: 10.3390/s23041856.
[51]. Knight SR, Ng N, Tsanas A, Mclean K, Pagliari C, Harrison EM. Mobile devices and wearable technology for measuring patient outcomes after surgery: a systematic review. *NPJ Digit Med*. 2021;4(1). https://doi.org/10.1038/s41746-021-00525-1.
[52]. Li H, Cheng L. A systematic review on hand exoskeletons from the mechatronics aspect. *IEEE/ASME Trans Mechatron*. 2024. https://doi.org/10.1109/TMECH.2024.3500585.
[53]. K. Lo, M. Stephenson, and C. Lockwood, "Effectiveness of robotic assisted rehabilitation for mobility and functional ability in adult stroke patients: a systematic review," Dec. 01, 2017. doi: 10.11124/JBISRIR-2017-003456.
[54]. Pehlivan AU, Sergi F, Omalley MK. A subject-adaptive controller for wrist robotic rehabilitation. *IEEE/ASME Trans Mechatron*. 2015;20(3):1338–1350. https://doi.org/10.1109/TMECH.2014.2340697.
[55]. Liu Y, Guo S, Yang Z, Hirata H, Tamiya T. A home-based tele-rehabilitation system with enhanced therapist-patient remote interaction: a feasibility study. *IEEE J Biomed Health Inf*. 2022;26(8):4176–4186. https://doi.org/10.1109/JBHI.2022.3176276.
[56]. Hesse S, Waldner A, Mehrholz J, Tomelleri C, Pohl M, Werner C. Combined transcranial direct current stimulation and robot-assisted arm training in subacute stroke patients: an exploratory, randomized multicenter trial. *Neurorehabil Neural Repair*. 2011;25(9):838–846. https://doi.org/10.1177/1545968311413906.
[57]. S. O'sullivan, et al. Legal, regulatory, and ethical frameworks for development of standards in artificial intelligence (AI) and autonomous robotic surgery. *Wiley Online Libr*. 2018;15:1. https://doi.org/10.1002/rcs.1968.